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INSTRUMENTS

INDUSTRIAL — SCIENTIFIC

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Devoted to Measurement and Control Problems

Vol. 3. No. 10 Pittsburgh, Pa. October, 1930

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M. F. BÉHAR

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Measurements—Industrial and Scientific
DR. WALTER BLOCK

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New Instruments:

- New Model Densometer
- New Type Instrument Current Transformer
- Two-Stage Oxygen Regulator
- Flush-Mounted Recording Thermometers and Pressure Gages
- A New Resistance Unit
- A New Potentiometer Pyrometer
- Vacuum Tube for the Measurement of Small Currents
- Krupp High Precision Mikrotast Pillar Stand

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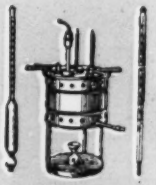
RECORDER - CONTROLLERS

AUTOMATIC CONTROLLERS

DIAL - INDICATING THERMOMETERS



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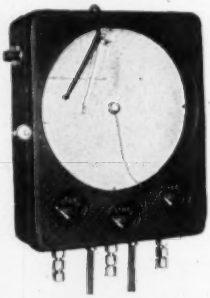

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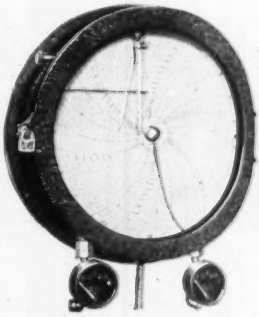

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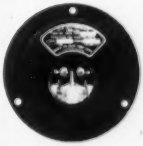
Model 30



Model 534
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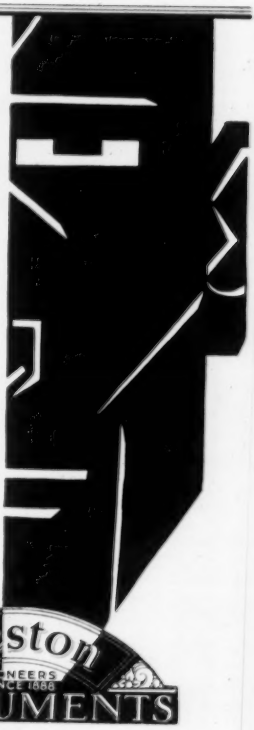
The BRAIN of the ROBOT



WITHIN recent years, the inventive genius of Industry has given to machines fingers that feel, eyes that see, ears that hear, noses that smell, tongues that taste. Yet when it came to the brain, the means to intercept, translate and direct the stimuli to produce the desired reactions, Industry turned to Weston. This time it was for special adaptations of the Weston Direct Current Relays.

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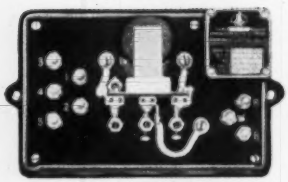
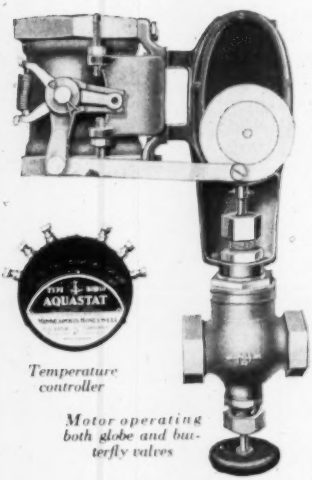


Typical Minneapolis-Honeywell relay for controlling circuits of electric furnaces or motor valves of oil or gas fired furnaces



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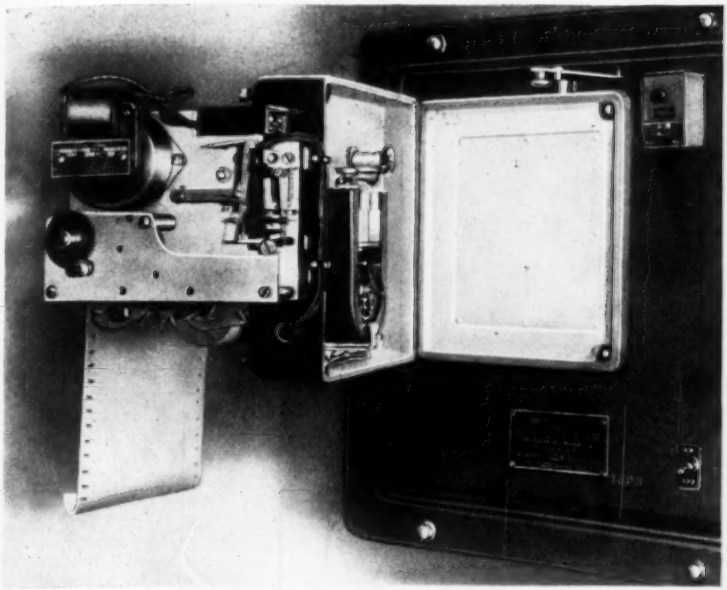

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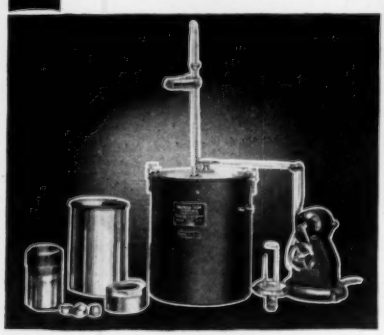
Oxygen Bomb Calorimeter—Standard Type. The Illium bomb, a jacket construction which insures minimum radiation, the efficient circulation of the water and accuracy of temperature measurement—these are the attainments which mark this instrument. (Below)



Oxygen Bomb Calorimeter—Adiabatic Type This instrument offers all of the advantages possessed by the Standard type. In addition, a water jacket entirely eliminates radiation. Ease of operation and speed make it unsurpa ssedfor determining calorific values. (Above)

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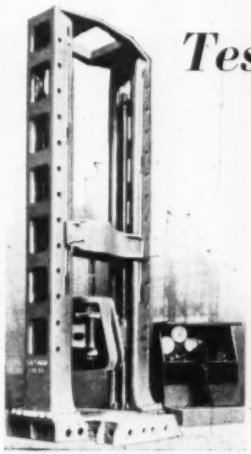

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Practical Steel Making. By Walter Lister. 413 pages. Published for the INSTRUMENTS PUBLISHING COMPANY. 3619 Forbes Street, Pittsburgh, Pa., $7.25 postpaid.

Sandwiched in among the many duties devolving upon an active open-hearth superintendent, I put in a great number of hours studying it, for I found it in many places of absorbing interest. I have not read a book on iron and steel in the last fifteen years which was of such interest. S. A. Jackson, who wrote the foreword, is quite correct in his statement that students can get far more of practical benefit from the papers published by the various institutes and societies than from technical books, but in this respect the work of Lister comes as a very pleasant change. I am very sure it can be read with great profit, not only by the student but by those who have added a few years of practical operating experience to a technical knowledge.

This work is a very painstaking and truly noteworthy effort, covering the entire field of steel making with the exception of the crucible method. Some sections are much stronger than others in authoritative statement. For example the open-hearth and electric furnace methods are well considered, but the Bessemer processes are viewed in too pessimistic a light, being consigned to the realm of inferior steel products. This is not justified by fact, considering the present day investigations concerning acid Bessemer steel and the fact that it suits many products from which it has been crowded by open-hearth steel. Again it must be borne in mind that the Germans have very successfully competed against the open-hearth with basic Bessemer steel.

Some will not agree with Lister's views on acid practice and pitwork. The paper by de Maré on the acid process in American Iron and Steel Institute proceedings stands as a classic and, for that matter, a reference standard. The chapter on pitwork does not bring out, perhaps, the best accepted American and German standards. In the theory of uphill or bottom-cast pouring, the Germans have been particularly apt in getting at the foundations of successful practice.

Notwithstanding the fact that the steel making methods described are dictated somewhat by the raw materials available in Great Britain, the practical details of the charges, the working of the heat, and the kinds and amounts of additions as given, provide the student and operator with data to check his theoretical and practical ideas, and which are very seldom available in a reference work. The opportunity to refer to and check the efficiency of additions is very much worth while in itself.

Methods described for putting in basic open-hearth bottoms and the choice of materials for refractories do not represent what we call the best practice on this side of the water, but undoubtedly success has been obtained with these methods in Great Britain. A book on practical steel making probably does not require a thorough discussion of the most modern details of furnace construction and of auxiliary appliances. For that reason the author can be forgiven for the fact that the details of construction and repair and the description of auxiliary equipment do not cover the most modern types and practice (based, of course, on our American ideas of what is modern), but nevertheless they are given in a very practical way and provide very interesting and valuable comparisons.

The book under discussion is quite unique and valuable; as a matter of fact I cannot rate it by comparison against any other work of the kind, since I have not had an opportunity to read one of its particular scope in the English language.

F. T.

The Iron Age, January 30, 1930—371

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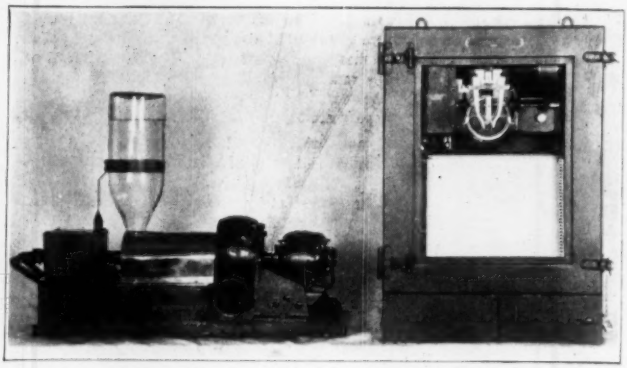
A Direct Reading Relative Humidity Recorder



Wetting Device and Humidity Recorder in Special Vapor-Proof Cabinet. Instrument shows relative humidity in per cent, without calculation.

This equipment makes a continuous record of relative humidity on a chart 9⅞ inches wide, calibrated from 20 to 100 per cent relative humidity. Within the temperature range from 32 degrees F. to 175 degrees F. it is sensitive to a change of 0.5 per cent relative humidity and the limit of error is 1.5 per cent relative humidity. The apparatus is particularly suitable for use with air conditioning equipment in textile mills, paper mills, tobacco storage and conditioning rooms, lithographing and printing plants and constant humidity test rooms.

The equipment consists, as shown above, of an L & N Recorder and a device for supplying to a wet-bulb electrical resistance thermometer a current of the air to be measured. Provision is of course made for supporting the dry-bulb thermometer near the wet bulb. The thermometers can be located at any distance from the Recorder.

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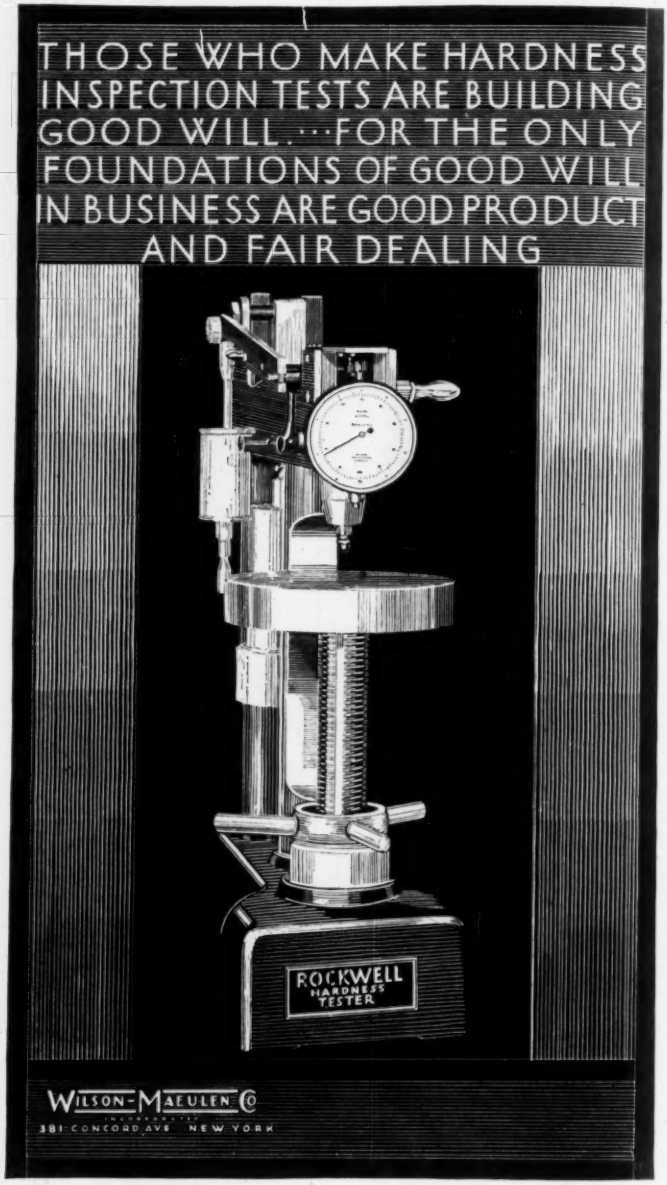
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INSTRUMENTS

INDUSTRIAL — SCIENTIFIC

(Reg. U. S. Pat. Off.)

Vol. 3, No. 10 OCTOBER, 1930 Pittsburgh, Pa.

To Our Readers

FOR the promptness with which INSTRUMENTS subscribers are sending in their ballots on the question of Metric *vs.* English weights and measures the editors extend sincere thanks.

This is the first nation-wide poll ever conducted on this question among thousands of engineers, manufacturing executives, and, in general, users of instruments, machines, laboratory apparatus, etc. It has begun to arouse such keen interest that we cannot refrain from publishing partial returns.

As this issue goes to press, a total of 2580 signed official ballots have been received and recorded.

The number of subscribers who checked "*I favor the general use of metric weights and measures in the United States*" is 1677, 65% of the 2580.

Those who checked "*I favor the continuance of our present system of weights and measures*" numbered 413, or 16%.

"*I favor complete decimalization of our present system of weights and measures*" was checked by 490, or 19%.

Such is the vote of INSTRUMENTS subscribers, of about 70% of them. These ballots are still dribbling in and in our next issue we probably shall be able to report the exact stand of an even greater percentage of our paid subscribers.

We delayed sending out the 70,000 ballots to non-subscribers in order to give our clerical force the benefit of practice in handling a smaller number. In response to inquiries about this now-begun "General Mailing," the following statement is made:

1. The attitude of INSTRUMENTS is neutral; its purpose is to determine the attitude of those concerned.
2. No one outside of INSTRUMENTS' editorial staff has influenced our selection of the mailing lists.
3. No official of either of the two societies which represent the "Metric" and the "Continuance" viewpoints is on our staff. *Both* societies, however, have approved the wording of our ballots as printed and distributed.
4. Not a single ballot will be sent to anyone whose name does not appear on any of the membership lists or directories which we have selected.
5. The General Mailing of ballots is going out to the membership lists of fifteen organizations and professional directories, which represent a cross-section of American engineering. These have been checked to eliminate repetitions of names.
6. These fifteen organizations include seven or eight which any thoughtful editor would select, and which have a combined membership of more than 60,000. The other organizations, etc., are our own selection for which we do not believe we are subject to criticism, but even if we were, their aggregate membership makes up less than 10,000 names.

7. The fifteen organizations are as follows:
American Chemical Society
American Electrochemical Society
American Foundrymen's Association
American Institute of Electrical Engineers
American Institute of Mining & Metallurgical Engineers
American Physical Society
American Railway Association
American Seismological Society
American Society of Civil Engineers
American Society of Mechanical Engineers
American Society for Testing Materials
American Welding Society
Institute of Radio Engineers
Journal of the Optical Society of America
Society of Automotive Engineers

It will be interesting to see how closely the results of this general balloting will follow those of the vote of our subscribers. We venture no prediction: The American engineering world will soon, for the first time, speak for itself in "significant" figures on this question. It will soon "say it with ballots" through the impartial medium of INSTRUMENTS.

INSTRUMENTS BOOK SHELF

The books reviewed in this section can be supplied by Instruments Book Shelf, Instruments Publishing Company, Pittsburgh, Pa.

Measurement by Positive Displacement Meters. Handbook E-4 Publication Department of the American Meter Company, New York, 1930. Paper, 206 pages, 6 by 9 inches. Price $1.00.

This book belongs to the ever-growing bibliography of practical manuals issued not by regular book publishers but by manufacturers. Ordinarily such publications are classified as "catalogs" and not as text books. Such a rigid classification, however, while it applies to the great bulk of manufacturers' literature, discriminates unjustly against the few exceptions. As to what constitutes an exception, it is difficult to put in words. The dividing line between a direction booklet for the user of a particular product, and a veritable text book such as "The Making, Shaping and Treating of Steel" issued by the Carnegie Steel Company, is a variable dependent largely on the personal equation. In this case, one would have to be prejudiced to declare after an examination of "Positive Displacement Meters" that it is merely a manufacturer's direction book concerning his own products. That it is far more, that it is of value to the gas industry and to gas meter users, that it is general in scope—these facts appear at first glance.

Section 1 on "Measurement of Gas" is a brief history as well as a description of present practice. Section 2 on "Physical Properties of Gases" constitutes an impartial treatise which any student would find of real help. So does Section 5 on "The Measurement of Gases at High Pressure and Vacuum." The concluding sections are of practical value: 7, "Testing Meters;" 8, "Critical Flow Provers;" 9, "Meter Maintenance and the Four Cardinal Points; 10 and 11, Meter Repairs.

This leaves only three sections which are purely descriptive of the American Meter Company's products: Section 3 "The Tinned Steel-Case Meter;" Section 4, "The Metric Ironcase Meter;" and Section 6, "The Meter Prover."

An interesting feature of the book is that there is no appendix. All tables and diagrams are placed in the text, next to the references thereto. No author's name appears: We quote from the foreword:

> "The compilation represents a cooperative effort. It is indebted to the writings of Gas Measurement Engineers throughout the country and to the careful collaboration of the executive personnel of American Meter Company under the editorial lead of John C. Diehl, author of the Natural Gas Handbook, and Chief Engineer of the Company."

Mr. Diehl and his collaborators are experienced in writing text books and numerous magazine articles for the gas industry, and the present work bears every evidence of thoroughness. Technically it appears to be up-to-date and authoritative. Only in a few paragraphs where the subjects discussed depart from the strict field of gas measurement, can there be any suggestion for improvement. An example to which the reviewer ventures to call attention is the unfortunate reference, under Physical Properties of Gases, on page 40, to the "space occupied by water vapor" in a mixture of air or gas with water vapor. Regardless of degree of saturation, it is an established fact that water vapor and gas jointly occupy the same space—entirely filling it. Therefore, to write of "the percentage of the volume occupied by water vapor" in discussing relative humidity is erroneous. Immediately following this discussion, two pages are devoted to the determination of atmospheric humidity beginning with the flat statement that "Two types of instruments are used, the stationary type in still or moving air and the sling instrument." As a matter of fact, these are but two of the four types in but one of the five classes of instruments for measuring atmospheric humidity; and for accurate determinations various types of absorption hygrometers and aspiration psychrometers are used in preference to these less accurate instruments. It would therefore have been well to refer—if only briefly—to other classes and types. —M. F. Béhar.

The Handbook of Industrial Instruments

M. F. Béhar*

CHAPTER IX

Industrial Humidity Instruments

(Continued)

5. Indicating Instruments

The variety of forms of hygrometric instruments is astounding—which fact is not surprising in view of the fact that European scientists and instrument-makers have been devising them since 1653 when a dew-point apparatus was discussed at the Florence Academy; and Americans for more than a century. Fortunately for the author and reader, most of these forms of instruments are non-industrial. In order of industrial importance (of indicating instruments) the psychrometer comes a good first; various hygrometers second and dew-point and chemical apparatus seem to find more use as checking devices than as indicating instruments for the plant conditions.

In the preceding section the five principles or methods of instrumental measurement were given. Re-arranging them in order of industrial importance we have psychrometry, hygroscopy, dew-point determination, evaporimetry and chemical methods.

For the sake of convenience we may divide the first method into two: true psychrometry, in which the true temperature of evaporation is obtained directly; and semi-psychrometry, which covers all other methods based on wet-bulbs.

From an industrial view point we have to segregate one "chemical" method from all others because it has now been made both practical and continuous. Reference is made to the thermal-conductivity method of gas analysis, which is the basis of an instrument developed for plant service in 1930. A new class is therefore added, making six, and the slightly expanded classification now follows:

I. Psychrometry (a) true psychrometry
(b) semi-psychrometry
II. Hygroscopy
III. Thermal conductivity
IV. Dew-point determination
V. Evaporimetry
VI. Absorption and other chemical methods

This list differs from the usual classifications which did not suit the purpose of this Handbook. The designation "hygrometer," for example, is almost universally applied to instruments of *two* distinct method-classes, the hygroscopic or capillary (hair, etc.) and the psychrometric (wet-bulb and dry-bulb). It will continue to be applied to both classes because the

*Engineering Editor.

TABLE IV—GENERAL CLASSIFICATION OF HUMIDITY INSTRUMENTS

(according to principle of measurement employed) with reference to Practicability and Availability for Industrial Purposes.

NOTE—In considering industrial humidity *recorders* and *controllers*, classification according to principle of humidity measurement employed is of minor importance, and therefore is not strictly followed in Sections 6 and 7.

CLASSES & TYPES According to Method Employed	Influenced by		AVAILABLE FORMS OF INSTRUMENTS Numerals refer to illustrations (I) Impracticable for such purpose (L) Laboratory rather than industrial			REMARKS Brief notes for quick reference ◄ See text for discussions
	Radiation	Motion of room air	Indicating	Recording	Controlling	
I. PSYCHROMETRIC						
1. Atomizing	No	No	I	I	191 to 193	Too costly for indicating or recording. Successfully applied to air conditioning installations. Correct method.
2. Aspiration	No	No	167, 168	185 to 187	194 to 196	Correct method.
3. Sling	Yes	No	165, 166	I	I	The "official" instrument though far from ideal. Tables are based on its readings under standard conditions of use.
4. Stationary	Yes	Yes	169 to 177	188	197 to 200	Of limited suitability where humidity alone is to be measured. Suitable for control where circulation over bulbs is adequate. Influence of other conditions may be an advantage.
II. HYGROSCOPIC						
1. Dimensional	Slightly	No	178, 179	189	201 to 208	Unreliable measurement (excepting the high-grade meteorological instruments) but dependable control.
2. Gravimetric	No	No	L	L	I	All laboratory instruments.
III. CONDUCTIVITY	No	No	.....	190	(Not yet ready)	The only "chemical" method made automatic and practical.
IV. CONDENSING	Slightly	Yes	L	I	I	For checking and standardizing industrial instruments.
V. EVAPORIMETRIC	Yes	Yes	180	L		Industrial process controllers actuated by loss of moisture from **materials** are not humidity instruments. They are discussed in subsquent chapters.
VI. CHEMICAL Absorption / Saturation / Compression / Etc. — Gravimetric / Volumetric / Piezometric / Etc.	No	No	181 to 184 L	I or L	I	All apparatus rather than instruments. All methods capable of high accuracy. Some methods employable industrially for measuring humidity in gases or in gas-and-air mixtures for which psychrometric tables are not available. Also used for checking and standardizing industrial instruments.

usage has taken root and because all humidity measuring instruments—etymologically and scientifically—are *hygro*-meters, so that headings I, II, III, IV and VI are the five logical divisions of hygrometry. Therefore, instead of trying to combat an inconvenient but justified terminology, the above list "gets around" the embarrassment by recognizing all accepted meanings and by simply omitting the unsubservient term "hygrometer." Thermometric hygrometers belong in Class Ib; hair or membrane hygrometers (hygroscopes, hygrophants, polymeters, etc.) belong in Class II. Class V does not belong in a list of hygrometric instruments: evaporimeters do not really *measure* humidity, but practical considerations dictate their inclusion. Likewise, the practical viewpoint advises describing in this section other miscellaneous aerological instruments which are not strictly humidity-measuring devices. Since they employ the wet-bulb principle to some extent, they will be discussed under psychrometers.

While this section deals only with indicators, references to recorders and controllers will perforce be made when describing in turn the various methods of measurement. Such descriptions, applying to the primary elements of recorders and controllers, will not be repeated in Sections 6 and 7.

With the above in mind a general tabulation of all humidity (and some aerological) instruments has been prepared. Table IV is thus a practical reference for engineers, and is not designed as a scientific tabulation.

Class I. Psychrometric Instruments

The classification of psychrometric instruments in Table IV is based on the closeness with which each of the four distinct methods involved approaches the ideally perfect method of measuring humidity by the simultaneous determinations of the true dry-bulb temperature and of the true wet-bulb temperature. Since the dry-bulb presents no special problem outside of thermometry, it comes down to their respective degree of accuracy of wet-bulb temperature measurement—a characteristic of such importance in engineering work that it suggests the division of the psychrometric class into *graded types*.

We are not referring here to the degree of accuracy imposed by the construction of a particular make, model, or individual instrument, but to the correctness or incorrectness of the method with regard to the measurement of humidity. There are four methods; hence four types of psychrometric instruments. Obviously, an instrument of a type which is influenced by factors other than humidity cannot be classified as of the same type as one whose principle excludes all such other factors.

Spray and aspiration psychrometers isolate a continuous sample of air, pass it through a "dark" chamber, protected against radiation, and moreover pass it over the wet-bulb at a high and constant velocity—a rate of motion which is independent of the motion of the air in the room or apparatus from which the continuous sample is drawn. In these two types of psychrometers, everything is done in order to measure two magnitudes only: the dry-bulb temperature and the *true* or "theoretical" wet-bulb temperature, that is to say the temperature of evaporation at the prevailing percentage of saturation, or the temperature of adiabatic saturation.

The sling psychrometer is whirled in order to reduce wet-bulb error but its bulbs are not shielded. The ordinary "stationary" hygrometer and other instruments of that type give wet-bulb readings which are *irregularly higher* than the true psychrometric wet-bulb temperature.

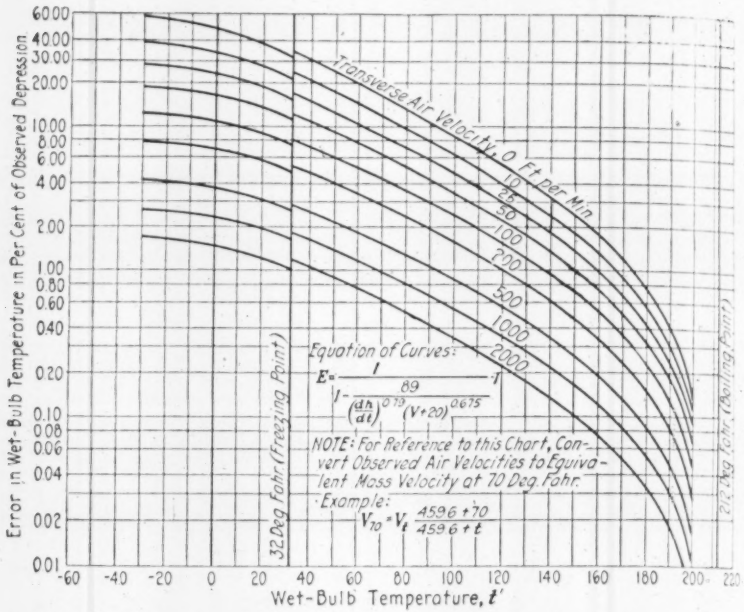


Fig. 164. Velocity error in wet-bulb temperature expressed in per cent of the observed depression at wet bulb temperatures from −30 to 200°F and at transverse air velocities from 0 to 2000 ft. per minute. (Carrier and Lindsay).

TABLE V—WET BULB TEMPERATURES (DEG. FAHR.) HAVING THE SAME PERCENT VELOCITY ERRORS AT VARIOUS BAROMETRIC PRESSURES

Example. Observed wet bulb temperature 50°F. Velocity 1000 ft. p. m. Barometric pressure 25". Table shows that 50° at 25" has same error as 55.9° at 30". Fig. 164 shows that at 1000 ft. p. m. its value is 1.25%

Barometric Pressure		30"	29"	28"	27"	26"	25"
Over Ice	10	9.2	8.4	7.7	6.9	6.0	
	20	19.2	18.4	17.6	16.8	16.0	
	30	29.2	28.4	27.6	26.8	26.0	
	32	31.2	30.4	29.7	28.8	28.0	
Over water	32	31.9	29.9	28.8	27.6	26.5	
	40	39.0	37.8	36.8	35.6	34.4	
	50	48.8	47.7	46.5	45.3	44.1	
	60	58.8	57.7	56.5	55.3	54.1	
	70	68.7	67.6	66.3	65.1	63.8	
	80	78.7	77.4	76.1	74.8	73.5	
	90	88.7	87.3	86.0	84.7	83.3	
	100	98.6	97.2	95.8	94.4	93.0	
	110	108.6	107.1	105.7	104.2	102.8	
	120	118.5	117.1	115.6	114.0	112.6	
	130	128.4	126.8	125.3	123.6	122.1	
	140	138.4	136.8	135.3	133.6	132.0	

Therefore, spray and aspiration instruments are capable of results whose accuracy, for all engineering purposes, may be called absolute—the limit of error falling well within the most exacting tolerance. The readings of a properly used sling psychrometer, referred to tables and charts based on Carrier's coefficient—formula (27) above—can give satisfactory results. Other psychrometric instruments, with unshielded and unventilated bulbs, do not give readings from which *humidity* can be determined more than roughly, *but*—and this is an important but:

There are cases where it is desired that the bulbs be subjected to exactly the same *conditions* as those to which the *occupants* of a room or the *materials* in a room or dryer are exposed. In such cases the bulbs must not be shielded, must not be ventilated—must be influenced not only by the prevailing humidity but also by the prevailing air motion and by the prevailing thermal radiation. In such cases, it should be borne in mind that the instruments measure "humidity plus." If they are well designed and constructed, their indications can be consistent and reliable, with negligible variance, and hence of actual value for whatever the purpose may be—such purpose, let it be repeated, being other than the exact measurement of humidity.

Velocity Error—Since the present subject is humidity instruments, the term "error" is applied with special reference to humidity measurement. There are two principal sources of errors in both dry-bulb and wet-bulb thermometers. These are *radiation* and *velocity*. Thermal radiation affects both the dry-bulb and the wet-bulb when these are unshielded, but the value of the error is ordinarily small. The velocity error pertains only to the wet-bulb and is far more serious. Centuries ago the phenomenon of wet-bulb depression was observed and almost a century ago it was definitely established that the wet-bulb must be exposed to lively circulation in order to give *consistent* readings. It was not until the 1924 annual meeting of the American Society of Mechanical Engineers, however, that Carrier and Lindsay presented their 20,000 word paper on "The Temperatures of Evaporation of Water into Air." (Note the plurality of "temperatures.") In this paper, which represented four years of new and special experiments, they reported for the first time the tabulated values of the wet-bulb error at different temperatures and different velocities. At "zero" circulation and at the common room temperature of 65°F, the value of this error is such as to infer a relative humidity of 54% when the true relative humidity is 44%.

Wet-bulb error varies not only with velocity and with temperature but also (obviously) with relative humidity. In saturated air, all types of psychrometric instruments will give equal readings for the dry-bulb and wet-bulb (if radiation effects are excluded, of course). It is at lower percentages of relative humidity that the wet-bulb error becomes considerable. At 65°F dry-bulb and 10% relative humidity, an unventilated wet-bulb would indicate a relative humidity of 26%.

The lower the temperature, the greater the value of the wet-bulb error—circulation and relative humidity being equal. At 42°F dry-bulb and zero velocity, 40% relative humidity would be indicated instead of 26% true value. The error is considerable however, at all temperatures within the comfort range.

Since the value of the velocity error is greatest at low relative humidities, when the wet-bulb depression is at its highest value, the error can conveniently be plotted in terms of wet-bulb depression. Carrier and Lindsay

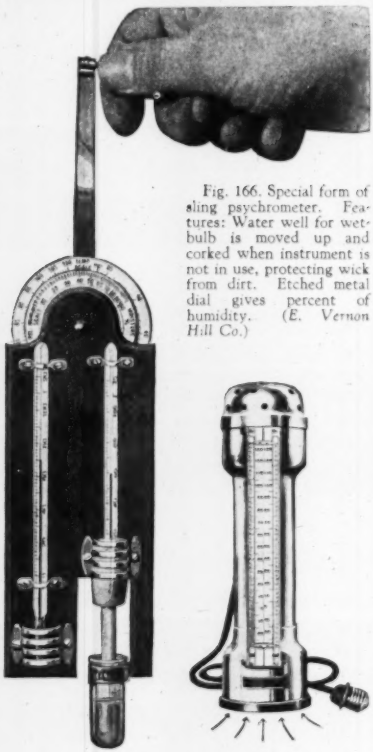


Fig. 166. Special form of sling psychrometer. Features: Water well for wet-bulb is moved up and corked when instrument is not in use, protecting wick from dirt. Etched metal dial gives percent of humidity. (*E. Vernon Hill Co.*)

Fig. 165 (Above). Two forms of sling psychrometers. The larger instrument has 12-inch thermometers graduated in one-degree divisions. The smaller instrument, on the table, is a convenient pocket model. (*Taylor Instrument Companies* instruments; *Carrier Engineering Corporation* photograph.)

Fig. 167 (Right). Cross-section of an Assmann aspiration psychrometer of German make. *a*. bulbs. *bb*. inner tunnels. *cc*. annular air spaces for eliminating influence of radiation. *qq*. fan blades. *t*. spring motor. *u*. exhaust ports. The thermometers are held by friction in metal caps *m* and may be slid out through the bottom of the instrument. Either thermometer may be used as the wet-bulb thermometer. The thermometers are usually of range 0 to 50°C and can be read to one-fifth of a degree. (Illustration reproduced from Bongards' *Feuchtigkeits-Messung*.)

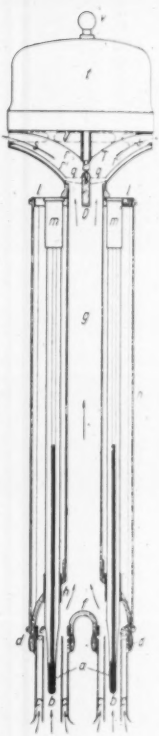


Fig. 168 (Left). American electric motor-driven aspiration psychrometer of the Assmann type but modernized with built in reservoir, etc. Air velocity is 1200 ft. p. m. (*Julian P. Friez & Sons.*)

INDUSTRIAL FORMS OF ASPIRATION AND SLING PSYCHROMETERS

not only determined for the first time the exact values of the velocity error but also definitely established the fact that it is proportional to the depression, regardless of the temperature at which it occurs. They computed the values of the velocity error for the entire useful range of temperatures and velocities and recorded them in a graph giving the values of the error in terms of percent of the true, theoretical wet-bulb depression. They then produce a slightly different graph giving the error in percent of the *observed* wet-bulb depression. This second graph is of distinct practical value and is reproduced by permission of Messrs. Carrier and Lindsay (Fig. 164).

Barometric Correction—The velocity errors, as recorded for various temperatures and velocities, were computed for a barometric pressure of 30 inches. The wet-bulb error varies slightly with barometric pressure, and for accurate work it is advisable to refer to the table below Fig. 164, which is for use in referring to the Fig. 164 wet-bulb temperatures observed at barometric pressures other than 30 inches.

From this table it may be seen that regardless of the value of the velocity error a barometric correction is applied to the *observed* wet-bulb temperature. Therefore this same table can be used to correct any wet-bulb reading—even one obtained from a high-velocity aspiration psychormeter not subject to velocity error—whenever it is suspected that the barometric pressure is low enough to introduce a negative error in the wet-bulb indication.

Type 1—Atomizing or Spray

In this type of instrument the wet-bulb is not covered by a moistened wick or sleeve but it is located in a chamber through which passes air which has been saturated adiabatically so that it is at the theoretical wet-bulb temperature, the true temperature of evaporation. While indicating and recording instruments have been made by various concerns, such instruments were apparently used in the development of the controllers utilizing this method, rather than for commercial models. The comparatively high cost of an installation, the necessity for employment of compressed air, the fact that from one to two gallons of water a day are consumed and that a large volume of saturated air is discharged, militates against the employment of this method for indicating or recording instruments designed for plant use. For automatic control the method is excellent, especially when compressed air relays are used in the control system or when the spraying device is itself a part of the air conditioning apparatus (see Section 7).

Type 2—Aspiration

The usual arrangement surrounding the bulbs of the aspiration psychrometer consists of two parallel tubes or tunnels through which air is drawn at a high and uniform velocity. The fan is always of the exhaust type, because if it were placed up-stream, the heat of the motor would tend to make both dry-bulb and wet-bulb indications too high. In some forms the tunnels consist of two pairs of concentric tubes, the outer surface of the outer tube being highly polished in order to eliminate entirely all radiation effects. Such is the arrangement of the Assmann aspiration psychrometer (Fig. 167) an instrument of German origin.

For the indicating aspiration psychrometers, mercurial thermometers are almost exclusively used—carefully matched high-grade thermometers, of course, with graduations engraved on the stems. Electrical resistance systems and pressure-spring thermal systems of the distance type (bulb,

connecting tube and spring) appear to be employed only in the recording and controlling instruments. The method of keeping the wet-bulb moistened does not seem to matter much—any arrangement which is suitable for the particular form of the thermometer bulb employed will do. In the Assmann psychrometer, either bulb is covered with a tubular wick which is moistened, just before an observation is made, by means of a device specially made for the purpose. This device consists essentially of a rubber water-bag small enough to be squeezed in one's hand, into the mouth of which fits a glass tube which one raises up into tube *b* (Fig. 167).

Cleanliness of water is not as important as purity of water. The presence of particles of dirt does not affect the readings until incrustation is noticeable. Impure water, containing other substances in solution, may cause wrong readings from the very start. Since the aspiration psychrometer is an instrument of precision it is almost imperative to use distilled water.

A good way of checking the matching of the two thermometers is to remove the wick or sleeve from the wet-bulb. The thermometers should then give the same reading. In high-grade aspiration pyschrometers the deviation from equality in this test should not exceed one-fifth of a degree Fahrenheit when the thermometers are of sufficiently short range to be read that close. Otherwise, the difference should not be visible to the naked eye.

Type 3—Sling

This form of instrument is the one employed for many years by the U. S. Weather Bureau for all government stations. It combines simplicity and low cost with a high degree of accuracy of method. There should be at least one sling psychrometer in every plant or department of a plant, or outdoor station, where knowledge of atmospheric humidity is desired. Sling psychrometers are made in various forms, including "jack-knife" folding pocket instruments, by several manufacturers. They consist of a pair of carefully matched thermometers with means for whirling and means for moistening the wet-bulb.

From the U. S. Weather Bureau, the National Bureau of Standards, the American Society of Heating and Ventilating Engineers, the Taylor Instrument Companies, the Carrier Engineering Corporation, the Parks-Cramer Co., the E. Vernon Hill Co. and other sources engineers may obtain detailed discussions and thorough directions on the use of the sling psychrometer, as well as various psychrometric tables and charts. The charts reproduced in small size in Section 4 of this chapter and the tables and charts included in the Appendix, should prove suitable for almost every industrial purpose. The following instructions, compiled from some of the above-named sources, and slightly supplemented, should also prove amply sufficient.

Take Several Readings—Perhaps the most important thing to remember is that writing materials are necessary adjuncts. Your first two observations will furnish the reason: as a rule they will disagree. Whirl, read; whirl, read; whirl, read; . . . until the wet-bulb indications are consistent. If inexperienced or out of practice, disregard the first two sets of readings and take the mean of the next two, three or four—that is to say the mean of a satisfactorily consistent series.

Read the Barometer—For accurate determinations at high altitudes or when atmospheric pressure is significantly low, apply the corrections given in Table V.

Use Clean Water—Ordinary tap water contains a small amount of suspended matter and dissolved impurities. The suspended matter tends to clog and harden the meshes of the wick. Substances in solution in the water may raise or lower its temperature of evaporation. Therefore it is best to use distilled water, which is available in most plants and if not in the plant itself, in the nearest battery service station or drug store.

Keep Wet-Bulb Clean—The simplest rule is, "Never touch the wet-bulb with your fingers." If even a small portion of the surface of the wet-bulb is covered with non-volatile substance such as oil or the waxy residuum of perspiration, the reading of the wet-bulb will be higher than the true temperature of evaporation. The tubular wicking supplied by makers is so inexpensive that whenever it is believed to have become dirty, it should immediately be renewed. The fabric should fit closely over the bulb, covering it entirely. Whenever the wick is replaced, it should be tied with fine thread above and below the bulb in order to cover it completely.

Minimize Radiation Effects—It is hardly necessary to mention that when observations are made outdoors on a sunny day they should be made in the shade. Indoors, too, it is well to try to minimize the effects of radiation from any source of radiant heat whatever—even from one's own body. And in order to minimize the heat effects of one's own body through convection currents, it is also well to step from side to side while whirling the instrument. For similar reasons it is better to face the wind outdoors (or the circulation indoors) so that the psychrometer will not be on the "leeward" side of one's body.

Get the Lowest Possible Wet-Bulb Reading—This is an important rule to follow, because wet-bulb error is almost always a positive error. For this reason the wet-bulb should always be read first, immediately after the observer has stopped whirling the instrument, as it begins to rise upon stopping the motion. However, one should not strive for a fictitiously low reading by using very cold water, whirling for a few seconds and immediately taking the reading. The water should ideally be initially at the wet-bulb temperature, but a difference of ten degrees or so does not cause erroneous readings if the whirling is continued for 45 seconds.

The Knack of Whirling—This may be compared to aviation—where the greatest skill is required in landing. In using the psychrometer, it is not difficult to set it in motion and keep it whirling at two to four revolutions per second for 30 to 45 seconds, but a certain amount of skill is required to stop and read in the least possible time. This is easily acquired after several trials.

Type 4—Stationary Psychrometric Instruments

These includes not only the ordinary wet-and dry-bulb hygrometers but also instruments of which the bulbs are exposed to the circulation which prevails in ducts, dry kilns, etc., where the velocity is sufficient to increase the wet-bulb depression, producing readings which are comparable to the true psychrometric readings. To this type also belong those instruments which are purposedly exposed to the prevailing conditions in order to measure not so much the humidity as the effective temperature. Finally, several forms of *single*-thermometer instruments.

Wet- and Dry-Bulb Hygrometers—Modernized forms of these familiar instruments include models provided with charts and tables. Fig. 169 shows one such instrument in which the printed table is wound on two

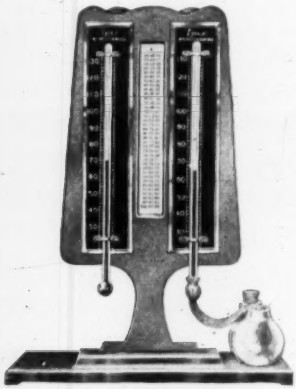


Fig. 169 "Hygro-Autometer." Wet- and dry-bulb hygrometer provided with a revolving paper chart which gives the relative humidity and the dew-point. (*Taylor Instrument Companies.*)

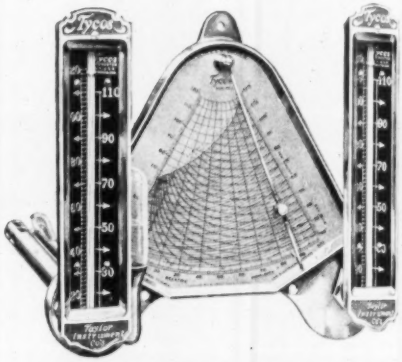


Fig. 170 "Angle Hygrodeik" for enclosed spaces such as air ducts, dry kilns, etc. Thermometers have 7-inch scales and 12-inch (or longer) stems. Between the two thermometers is a humidity chart. The scale on the left side of the chart corresponds to wet-bulb temperature; right hand scale for dry-bulb; relative humidity scale at the bottom of the chart. (*Taylor Instrument Companies.*)

Fig. 171

Remote indicating system for bringing the dry-bulb and wet-bulb temperatures of a number of rooms in a building to a central station. Fig. 171 shows a room instrument with dry-bulb and wet-bulb elements, the latter encased in a glass tube covered by a wick kept moistened by a glass reservoir. The panel board shown in Fig. 172 has a millivoltmeter indicating instrument with a scale graduated from 10°F to 160°F together with a special complementary scale giving the desirable dry-bulbtemperature for any wet-bulb temperature and vice versa. The wet-bulb push button for any room in first pressed; the reading observed, then the dry-bulb button is pressed and the reading compared with the complementary temperature of the wet-bulb on the "comfort scale." (*The American Temperature ndicating Co.*)

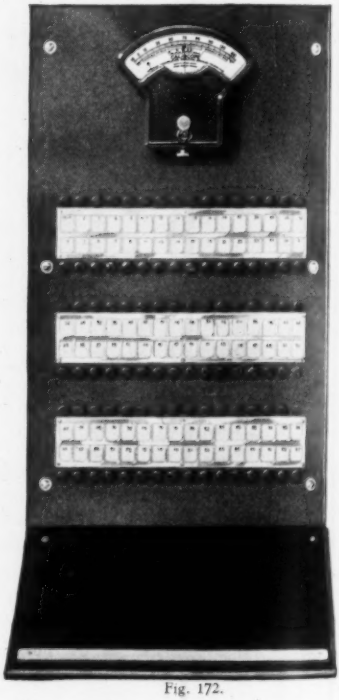


Fig. 172.

FORMS OF WET-BULB AND DRY-BULB HUMIDITY INDICATING INSTRUMENTS

rollers so that space is economized and convenience attained. Fig. 170 shows an angle form designed especially for application to ducts, kilns, etc. —both bulbs protruding through the wall to which the instrument is fixed.

For remote-indicating hygrometers, the electrical resistance thermometric system is employed in industrial installations (Figs. 171 and 172) but not the pressure-spring thermal system, to the best of our information, except insofar as indicating systems constitute elements of recording or control installations.

For many years Glaisher's tables and other similar tables have been referred to in connection with the readings of stationary hygrometers. Carrier and Lindsay have proved that these are altogether unreliable, by demonstrating that the wet-bulb error in still air may amount to more than 20% of the depression. It therefore is always advisable, when the purpose of the instrument is to measure humidity, to calibrate it under the conditions of its use—if these are constant. For this purpose an aspiration psychrometer or a sling psychrometer should be used, and the wet-bulb thermometer correction factor recorded on a card hung next to the instrument. The dew-point apparatus or any other accurate humidity measuring instrument can also be used for such purposes.

It cannot be too strongly emphasized that there is no such thing as perfectly stagnant air in the proximity of a wet-bulb. The conditions surrounding a wet-bulb are entirely different from those which prevail in the case of a tall glass partially filled with water free to evaporate into room atmosphere. In the latter case, there are no convection currents from the surface of the water to the air above, as the lower layer of air is colder than the room air, and moreover, the saturated air at the surface of the water is denser than the unsaturated room air. In the case of a wet-bulb, even if the room air is perfectly motionless, the evaporation from the surface of the wet-bulb induces a downward current because the air which comes in contact with it is both colder and denser. But it is precisely at low and uncertain velocities that the highest wet-bulb errors occur. In general it may be concluded that stationary instruments are unsuitable for measuring humidity in rooms where drafts are variable, but are suitable for such purpose in ducts and enclosed apparatus where there exists a *constant* artificial circulation.

The Kata-thermometer—For the very reason that instruments which are best for measuring humidity must isolate samples of the air, these instruments are unsuitable for measuring the combination of humidity and other conditions to which are exposed the persons in a room. More than one hundred years ago a Dr. W. Heberden, in order to study the conditions of the air in a sick-room, heated a short-range thermometer to 100°F (approximate body temperature) and *timed its rate of fall.* This rate of fall, in the case of a dry-bulb thermometer, depends on radiation and convection; in the case or a wet-bulb thermometer, it depends on radiation, convection and evaporation. In 1913 Dr. Leonard Hill revived Dr. Heberden's method and devised the modern Kata Thermometer (from κατα, cooling down.) Griffiths in England perfected it in 1915, and it was shortly thereafter approved by U. S. authorities.* The modern Kata Thermometer may consist of a pair of carefully matched short-range spirit thermometers with very large bulbs and with stems accurately graduated from 95 to 100°F,

*See report of Committee on Standard Methods for Examination of Air, American Public Health Association—American Journal of Public Health, Vo. 7, No. 1, Jan. 1917.

FORMS OF SINGLE-THERMOMETER AEROLOGICAL INSTRUMENTS

The difference between the air conditions required in industrial drying apparatus and those required in rooms for human occupancy is strikingly shown in the shaded portions of the two "duo-therm" charts. Fig. 173 shows one industrial model of this form of instrument, made up for a manufacturer of finishes. Note that the scale has a red zone extending from 35 to 45% relative humidity. In the room model (Fig. 174), the red zone corresponds only to the Effective Temperature comfort zone. Fig. 175 shows an improved American form of the Kata-thermometer, which can be used successively as a dry-bulb thermometer influenced by radiation and convection; as a dry-bulb protected against convection and influenced only by radiation; and as a wet-bulb thermometer. Figs. 176 and 177 show two forms of Effective Temperature thermometers. (*All instruments on this page—E. Vernon Hill Co.*)

Fig. 173

Fig. 174

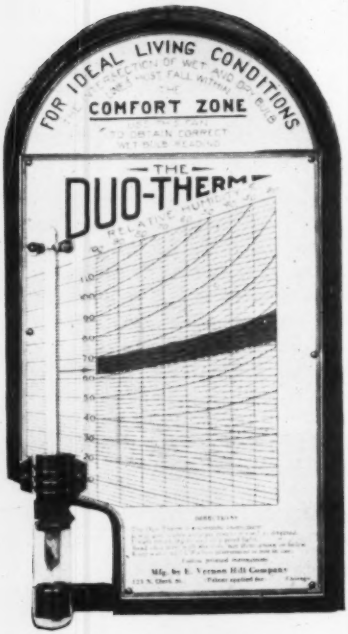


Fig. 175

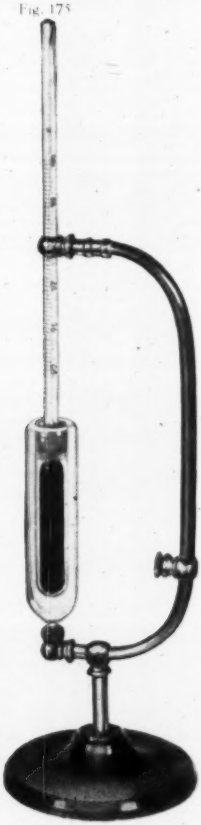
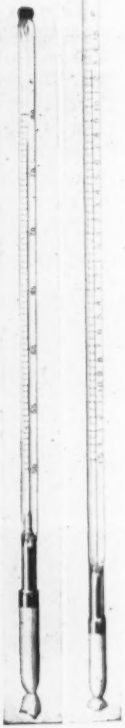


Fig. 176 Fig. 177



or to save cost one single thermometer may be used, successively as a dry-bulb and as a wet-bulb instrument.

The Radia-kata-thermometer (Fig. 175) is a very recent development which can be used also for measuring loss of heat by radiation. In studying room conditions this thermometer is used three times in succession for each set of readings: first "naked," then with a special radiation-loss device and thirdly as a wet-bulb instrument. In each case the thermometer is heated to about 110°F by being placed in warm water. The bath temperature need not be exactly 110°—the purpose of the heating being to send the liquid column sufficiently far above the 100 mark, well into the expansion bulb at the top. After being heated the thermometer is exposed to the conditions of the room under study. The time to fall from 100° to 95° is taken with a stop-watch. (The mean is 97.5 which is close to the standard body temperature of 98.4).

First the thermometer after being carefully dried, is cooled in the open. This gives the rate of cooling by radiation and convection.

Next, the thermometer bulb, after being heated and dried, is placed in a vacuum bottle as shown in Fig. 175. Thus insulated from heat loss by convection and evaporation, the rate of fall from 100° to 95° is a measure of the cooling by radiation alone.

Next the thermometer bulb is covered with a moistened wick and heated to 110°. It is then withdrawn from the source of heat and again the rate of cooling from 100° to 95° is observed. The rate of cooling depends this time on convection, evaporation and radiation.

From the lengths of these three cooling periods, and especially from the differences between any two, the comfort conditions in any room are determined not only with a high degree of accuracy but with reference to established standards.

Effective Temperature Thermometers—We have seen in Section 3 above that Effective Temperature is a term adopted by the American Society of Heating and Ventilating Engineers to denote the combination of temperature, humidity and air motion. Fig. 156 shows the effective temperature lines for still air conditions and Fig. 157 shows the effective temperature lines for 100 ft. per minute velocity. In recent years, as a result of these discoveries, there have been developed thermometers with two communicating bulbs, one dry and one wet, the mercury volumes and the bulb surfaces being so proportioned that the height of the mercury thread, when the covering of the wet-bulb is moistend and when the thermometer is exposed to the prevailing room conditions, will directly indicate the effective temperature without the use of charts or tables. In recent models the two bulbs have been replaced by a single long bulb, the wet and dry portions of its surface definitely separated and proportioned for each individual instrument by fastening the wick in place by cement and silver wire. There are two models, (Figs. 176 and 177) one gr duated in effective temperature degrees from "50" to "80" and the other with a scale marked 0 at the comfortable effective temperature of 64° and with each degree above or below this point marked 1, 2, 3, etc., up to 15. The scale is so arranged because the effective temperature scale means nothing to the average individual who is unfamiliar with effective temperatures, psychrometric charts, etc. In using this model the observer only need know that the maximum condition of comfort is zero on the scale (whence the trade name "Zero") and that the degree marks above or below represent departures from the desirable conditions.

The directions for use of these thermometers state that "to obtain accurate information as to comfort conditions it is only necessary to moisten the wet-bulb portion of the instrument, swing or gently shake it in the air until the indicating liquid reaches the lowest point, then read the scale. This gives the effective temperature directly without the use of charts or tables." It seems to the author that thus artificially ventilating the wet-bulb defeats the purpose of the instrument. In a room where the total lack of perceptible circulation of the moderately warm, moist air is decidedly uncomfortable, such a thermometer, if sufficiently fanned, would fictitiously indicate an effective temperature within the comfort zone.

Single-thermometer Hygrometers—The temperature of the water in a small corked flask is not the temperature of evaporation but the "room" or dry-bulb temperature. If a thermometer be inserted through the cork, and if evaporation be prevented, the thermometer will give the dry-bulb temperature. If the bulb of such a thermometer be covered by a wick—bulb and wick being immersed in the water but no evaporation taking place—the thermometer will still give the dry-bulb temperature. Remove the thermometer, cork and wick from the flask or "well," and that combination now constitutes a wet-bulb thermometer.

By successively reading the thermometer when its well is corked and when its wick-covered bulb has been withdrawn, one obtains the equivalent of a two-thermometer psychrometric instrument. If the wet-bulb is unventilated one has the equivalent of a stationary hygrometer; if the wet-bulb is vigorously ventilated one has the equivalent of a sling psychrometer.

This idea is employed in a line of convenient little instruments of which there are three principal models: (1) instruments consisting of a wood or metal back which is hung on a wall and to which the well is permanently attached while a handled thermometer may be detached and whirled, as is a sling psychrometer. (2) Instruments with a wood or metal back on which is imposed a chart designed for industrial purposes, as illustrated in Fig. 173. (3) Same construction, but the chart is an effective temperature or "comfort" chart, as illustrated in Fig. 174.

An excellent essential feature of all such "well" instruments is that the covering of the wet-bulb (or of the single bulb) is protected from dust and dirt when the instrument is not in use. And the distilled water lasts longer.

Comfort Thermometer—This is one thermometer, not a pair nor a thermometer with two bulbs. It only has a wet-bulb but its scale is double, the right side graduated in degrees F in the ordinary manner and the left side providing a scale (in red) which gives the desirable dry-bulb temperature for whatever wet-bulb temperature is indicated by the instrument. Above 64° the scales are reversed as a comfortable wet-bulb temperature cannot be obtained above this point. Above 64° therefore, the instrument is used as a dry-bulb thermometer and the complementary scale then gives the desirable wet-bulb temperature for the dry-bulb temperature shown.

Class II. Hygroscopic Instruments

Thousands of different organic materials respond to variations in atmospheric humidity by changes in linear dimensions, shape or weight. Many are excellent in that they make possible the manufacture of inexpensive hygroscopes. Only a few are acceptable for use as the primary element of

a hygro-*metric* instrument. Not one material combines all desirable properties such as—

(1) Humidity-dimension relation of such form that it can be expressed mathematically over the entire useful range in order to make it possible to design an instrument with a reliable scale.
(2) Quick response, high sensitivity.
(3) Low hysterisis.
(4) Negligible variance.
(5) Permanent calibration—no aging, fatigue, or deterioration.
(6) Unaffected by temperature variations.

Not one material—according to the best information in 1930—possesses both the first *and* the fifth properties to an extent at all comparable with those of the well-known thermoscopic fluids such as mercury, alcohol, nitrogen, etc.

The search for the ideal hygroscopic material still continues but for many decades human hair and animal membrane have both given fairly satisfactory results in hygroscopes, though each has its limitations. Human hair under moderate tension elongates nearly 3% from dry to saturated air.

The Parks-Cramer Company, alongside an illustration of the "Parkspray" Hygrometer (Fig. 178) in one of its own publications, prints, with commendable candor, the following:

> The hygroscope has proved of limited value except as a rough indicator of humidity for the following reasons:
> (1) The moisture content of hygroscopic materials at a given relative humidity is affected by temperature changes;
> (2) The slowness with which the material takes on and gives off moisture in response to atmospheric changes impairs its accuracy;
> (3) The readiness of the substance to take on dust, etc., from the atmosphere, soon causes deterioration or otherwise so affects the hygroscopic property that indications are generally unreliable;
> (4) The elastic properties of animal and vegetable substances are variable. Hygroscopic members are liable to take a temporary or permanent "set." This is especially true after prolonged exposure to a moderate or dry atmosphere.
> At best, frequent adjustments are necessary to make readings of the hygroscope conform to those of the sling psychrometer, the accuracy of which has been demonstrated. Nevertheless, the use of the hygroscope is sometimes recommended in locations where quick, easy reading is of more importance than accuracy.

On the other hand there may be cited the fact that the U. S. Weather Bureau has "officially adopted" a form of recording hygrometer in which the primary element consists of a number of selected, treated and matched human hairs. Which fact is of lesser importance to engineers when it is considered that the men who use these hygroscopic instruments for meteorological observations are government specialists who moreover use psychrometers and dew-point apparatus in order to calibrate these hygroscopic recorders.

The one great advantage of hygroscopic primary elements is that they obviate the need of thermal elements, thus simplifying the construction of instruments. For automatic control where "accuracy" is required only at one point (or only within a short range between two points), hygroscopic actuating elements of hair, membrane, wood, etc., give excellent results. See Section 7.

Fig. 178 shows an industrial form of hair hygrometer. Fig. 179 shows one form of the "metal spiral" hygroscope, a German instrument which is found in surprisingly large number in American plants. The hygroscopic material (a sort of wood-pulp—"just plain paper," we are informed) forms

a coating on one side of a metal spiral. The action therefore resembles that of a bi-metallic spiral thermometer—and it is reasonable to suppose that errors in humidity indication are caused by exposure to extremes of summer and winter temperatures unless the coefficients of thermal expansion of the metal and of the "paper" have about the same value, which is unlikely.

This suggests one important limitation of hygroscopes not mentioned above—their unsuitability for humidity measurement outside of a comparatively short temperature range.

The foregoing brief discussion refers only to the dimensional type of hygroscopic instruments. The gravimetric type is not made up in industrial forms. It consists essentially of a balance or of a spring-scale, with a pan holding a given weight of a hygroscopic substance. The higher the atmospheric humidity, the greater the weight of the substance in the pan. Recorders as well as indicators are manufactured in various forms, but all appear to be delicate laboratory instruments.

Class III. Thermal Conductivity

This is a very recent development (late 1930) and only one practical instrument has made its appearance—the Leeds & Northrup. The primary element is a comparison cell; the circuit is essentially a Wheatstone bridge; the measuring instrument is a potentiometer. No indicator has been made up—only a recorder, and therefore this class will be described in Section 6.

Class IV. Condensation

This class comprises only the dew-point apparatus, which is made up in several types and numerous forms. The simplest, readily available in any industrial plant, consists of a pitcher of ice-water, a polished metal cup and a sensitive etched-stem thermometer. The cup is half-filled with tap water; ice-water is slowly added and the mixture stirred with the thermometer which is read *twice*: the moment dew appears on the cup, and the moment it starts to vanish as the cup temperature slowly rises. The mean of the two readings is fairly close to the true dew-point. It will usually be a trifle high on account of heat from the observer's body. The mean of a series of observations, as in the case of the sling psychrometer, is the value to be obtained when accurate results are desired, no matter how crude or elaborate the apparatus may be. Modern commercial forms of the dew-point apparatus embody provisions for shielding the bright metallic surface from all undesirable outside influences, for regulating the temperature of the liquid (ether is frequently used) very slowly, for precision of surface temperature measurement, etc. It would appear that such modern refinements are only to be found in European-made apparata—the American-made devices seem to be designed for school laboratories rather than for industrial plants.

Class V. Evaporimetric

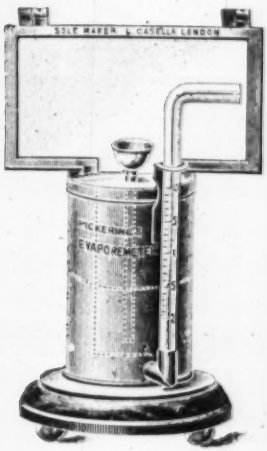
The evaporative power of the air depends principally on the prevailing "deficiency" which may be expressed in several ways as discussed in Sections 1 and 4. It also depends on the prevailing temperature. It also depends on the prevailing circulation in any processing room, storage room, etc. It may be calculated from the readings of hygrometric and anemometric instruments. It may be measured directly, however, by any instrument in which a sheet of linen, paper, etc., of definite area, fed with water from a graduated reservoir, is exposed to the prevailing conditions. Such an

instrument is illustrated in Fig. 180 (which is reproduced from an English catalog because a search through American literature failed to produce any comparable device.) It would seem that this class of instrument holds

Fig. 178

Fig. 179

Fig. 180



interesting possibilities in the way of eliminating complicated calculations and occasional guesswork in connection with industrial problems involving not so much the humidity of the air as its actual evaporative power.

No scale has yet been devised (at least, none has been adopted by any engineering body) for the evaporative power of air. Such a scale would no doubt resemble the scale of "effective temperature" as discussed in Section 3 above. Evaporimeters can only give the evaporative power of the air in arbitrary terms. Nevertheless, these terms can be always the same, can be standardized, by standardizing the construction of the instruments and their conditions of use. In the case of one instrument used in one plant, however, standardization is unnecessary and the only requisite is a log or notebook.

The following description and instructions are given by Messrs. A Gallenkamp & Co., Ltd., London:

This instrument affords a simple means of measuring directly the volume of water evaporated from a moist surface of known area. The moist surface consists of a piece of linen measuring 100 by 50 mm., held vertically, by means of a hinged frame, over a copper water reservoir fitted with a graduated glass side tube, as shown in the figure. The sheet of linen ends in a tongue, which dips into the water, and is thus kept damp.

The graduations are such that they give the number of units of volume evaporated per unit area exposed. Thus a fall of 0.24 shows that 0.24 cubic inch, or cubic centimeter, has evaporated from each square inch, or square centimeter, of the surface exposed.

To set the instrument, insert the linen in the frame and fix this in the cover previously removed from the vessel of water. Then wet the linen and place it and the cover on the vessel. Before reading the level of the water in the side-tube it is well to allow the linen to drain for a few minutes, and then the water should, by means of a piece of rubber tubing, be drawn up a short distance to make sure that the graduated tube is thoroughly wet. Care

should be taken that the side-tube is quite clean, and that there are no bubbles either in it or in the rubber tubing. The water should be distilled or rain water. It is not necessary to adjust the reading to zero, provided that the reading at the time of setting the apparatus is noted.

It is essential that the linen should be always moist all over; if it is found not to be so, this will probably be due to greasiness, and a fresh piece should be substituted. The same one, however, will generally remain effective for many weeks. Blotting or filter paper may also be used without influencing the results.

The amount of evaporation has been found to be uninfluenced by the actual level of the water in the vessel. A little evaporation occurs through the aperture in the cover. This

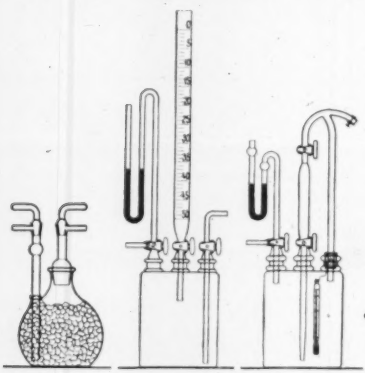


Fig. 181

Fig. 182

Fig. 183

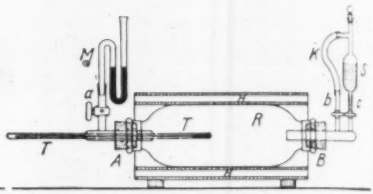


Fig. 184

amounts to about 3 percent of the total evaporation, and such a correction can always be applied, though, as a rule, it will be a negligible quantity.

The temperature when the instrument is adjusted and when the evaporation is read should be the same; if it is not, a fairly accurate correction may be applied by subtracting from the last reading .001 for every degree C., or .0005 for every degree F. that the temperature at the last observation is above that at the first observation, or vice-versa.

Both this, and the correction due to evaporation through the slit in the cover, may, however, be obviated by having a second instrument, similar in every respect to the former, except that in the latter case, evaporation from the linen is prevented by a strip of grease drawn across the neck of the linen. When the apparent evaporation* as indicated by this instrument is subtracted from that indicated by the first one† the true evaporation is obtained without further correction.

Class VI. Chemical

With the exception of one (the thermal conductivity hygrometer) all chemical devices for measuring humidity are forms of laboratory apparatus rather than of industrial instruments. Capable of exact results, they find industrial employment in checking and standardizing the practical every-day instruments and on that account deserve mention. Fig. 181 shows a form of absorption flask for the gravimetric method. Two forms of the sulphuric acid absorption apparatus in which the vapor pressure is obtained by the fall of the manometer are shown in Fig. 182 (H_2SO_4 in graduated burette) and Fig. 183 (pipette acid feed). The acid is fed drop by drop until equilibrium is reached. Fig. 184 shows an improved apparatus for this method, with lagging H around glassbottle R and an arrangement whereby after the acid in container S is released the manometer can be read after a minute or so, whereas the burette-fed apparatus requires hours. As for volumetric hygrometers, they are forms of the well-known Orsat apparatus.

*That is to say, the *actual* evaporation through the slit in the cover.

†During the *same* period, and both instruments being placed close together, exposed to the same conditions.

Measurement of Air Flow

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CHAPTER VI (Cont'd)

The Venturi Tube.—The factor which contributes mostly to the loss of head through a plate orifice is the sudden increase of area after the air has passed the orifice; the rapid convergence of the stream on the upstream side as it contracts to pass through the orifice is found to be of minor importance. The cause of the loss of head on the downstream side seems to be that the space between the boundaries of the jet and the walls of the pipe before the jet has expanded again to the full pipe area, becomes filled with "dead air," in a state of violent turbulence, in which an appreciable amount of energy is dissipated. If the transition from the full pipe diameter to the minimum section and the subsequent re-expansion to the full area are carried out gradually, by actually guiding the air through conical lengths of pipe of fairly small taper (see below), the pressure drop from the upstream entry to the minimum section, or "throat," may be in large measure recovered after expansion. An arrangement of this kind, in which the section of the pipe is gradually reduced and subsequently expanded to its original area, is called a Venturi tube, and it may, in certain cases where it is desired to avoid loss of head, be preferred to an ordinary orifice plate. It has the disadvantages that it is more expensive, and that its insertion in an existing pipe line necessitates more alterations and fitting than that of an orifice plate.

The Venturi tube is usually constructed of approximately the proportions shown in Fig. 28. The apex angle of the converging upstream cone is about 20°, and that of the diverging downstream cone about $5\frac{1}{2}$°, changes of slope being made through easy curves. In order to obtain good mean values of the static pressure at the entrance and the throat, these sections are usually surrounded, as in the diagram, by annular chambers, or "piezometer rings," connection being made to the inside of the tube by means of a series of small holes pierced round its circumference. Two tubes, one from each annular chamber, are led to a suitable manometer.

The slopes of the inlet and outlet cones have been fixed by experience. In order to reduce the wall frictional losses

through the Venturi to a minimum, it is obviously desirable to make the instrument as short as possible, i.e. to make the divergence and convergence as rapid as possible. As regards the exit cone, however, it is found that a diverging conical pipe having a total included angle of more than about 7° does not " run full," that is to say, there is a tendency for the boundaries of the stream to leave the walls and give rise to a " dead water " region which, as in the case of the jet from an orifice, leads to a loss of head. For this reason the exit cone must be long and gently sloping, the maximum permissible angle being about 7°. The

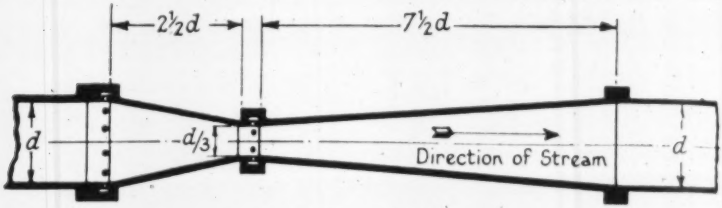


FIG. 28.—Venturi tube.

unavoidable increase in the wall friction consequent upon the long exit cone is small compared with the loss of head experienced if the exit cone does not run full. The inlet cone, in which there is no tendency for the stream to leave the walls, can be made considerably shorter with its walls sloping at a steeper angle. A limit on the slope is imposed in this case by the consideration that the throat of the Venturi must run full and that the direction of streaming there must be everywhere parallel to the axis of the pipe. If the slope of entry is too steep there is a tendency for a vena contracta to be formed in or near the throat. It is probable that an entry of a form similar to that of a shaped nozzle (see Fig. 30) could be used with advantage and be considerably shorter than the conical inlets in common use on Venturis; but it would, in view of the more careful shaping necessary, be more expensive to construct than a simple converging cone. In practice, a 20° conical inlet is found to fulfil requirements and has been generally adopted.

The quantity of air flowing per minute through a Venturi is calculated by the use of equation (12), the quantity r now being taken as the ratio of the area at the commencement of the entry cone to the area of the throat, whilst h_1 and h_2 are the pressures at these sections. As in the case of the orifice, if $\frac{p_2}{p_1}$ is less than about 0·98 the value of the compressibility factor C in equation (12) begins to differ appreciably from unity, and must be determined. Since the minimum area of the jet in a properly designed Venturi is equal to the area of the throat, there is no need to apply a correction, similar to that necessary for a plate orifice, to the value of r in calculating C.

The coefficient of discharge α of a Venturi is, on account of the absence of any contraction of the stream after it issues from the throat, considerably greater than the normal discharge coefficient of a plate orifice, being, in fact, usually between 0·95 and 0·98. There does not, unfortunately, appear to be sufficient published information to enable the coefficient to be stated with a great degree of precision. In the first place, no particular design of Venturi has been adopted as a standard, and, as was pointed out in discussing orifice discharge, the coefficient must to some extent depend upon the shape and proportions of the constriction. Secondly, most of the published data obtained from systematic tests relate to the flow of water. A useful analysis of these data has been made by the American Society of Mechanical Engineers in their Report on Fluid Meters (Part I.), where the information is presented in such a form that it may be applied, within certain limits, to the flow of air.

We have already seen (equation (11)) that the coefficient α in the case of the flow of an incompressible fluid through any one of a series of geometrically similar constrictions is some function of the quantity $\frac{v_2 d_2}{\nu}$, where v_2 and d_2 are the velocity at the throat and the diameter of the throat respectively, and ν is the kinematic viscosity of the fluid. All the quantities must be in terms of a consistent set of units—in England the foot-pound-second system is usually adopted. It has also been shown that the use of this criterion is not restricted to any particular fluid. For instance, two constrictions geometrically similar to each other will have the same values of α when one is delivering air and the other water, provided that $\frac{v_2 d_2}{\nu_{\text{air}}}$ for the one is equal to $\frac{v_2 d_2}{\nu_{\text{water}}}$ for the other, and provided also that the pressure changes in the air are small enough to warrant its being regarded as incompressible. We can thus make use of a water calibration to predict with confidence the discharge coefficient for air, since at the same value of $\frac{v_2 d_2}{\nu}$ the coefficients will be the same. This statement, which is a particular instance of the general law of "dynamical similarity" as applied to fluid motion, has a rational theoretical basis and has been fully substantiated by experiment.

Making use of this law, the American Society of Mechanical Engineers * have plotted on a base of $\frac{v_2 d_2}{\nu}$ reliable data, obtained from various experimental sources, relating to Venturi coeffi-

* *Loc. cit.*

cients, and have found that a mean curve can be drawn through all the experimental points, none of which shows a departure exceeding $2\frac{1}{2}$ per cent. of the mean value of α given by the curve. Included in the data are figures for Venturi tubes having $\left(\frac{\text{maximum diameter}}{\text{throat diameter}}\right)$ ratios ranging between 2 and 3. Strictly, such a curve could only be expected to apply to geometrically similar Venturi tubes of constant ratio, but the fact that such good consistency is actually found indicates that a departure from similarity between the above limits does not seriously affect the value of α. The curve is reproduced in Fig. 29 on an actual base of log $\frac{v_2 d_2}{\nu}$ instead of $\frac{v_2 d_2}{\nu}$. This method of plotting is adopted in order to include all the data in a diagram of reasonable size; plain plotting on a $\frac{v_2 d_2}{\nu}$ base would necessitate a very long figure or, alternatively, one in which the region relating to the higher rates of flow would be unduly compressed. The American Society of Mechanical Engineers consider that values of α taken from this curve may be regarded as accurate within 1 per cent. for Venturi tubes of normal commercial design and construction under normal conditions of installation and operation, to which proviso must be added, in the case of air flow, the condition that the ratio $\frac{p_2}{p_1}$ should not be less than 0·98.

A variation of α with $\frac{p_2}{p_1}$, of a nature related to the similar variation observed with plate orifices, has been recorded by Gibson * in tests on a small Venturi having a throat diameter

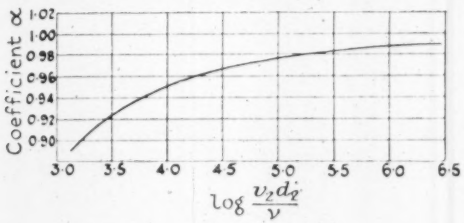


FIG. 29.—Venturi coefficients.

of $1\frac{1}{2}$ inches in a 3-inch pipe. He found, as shown in Table IV., that α increased by about 8 per cent. as $\frac{p_2}{p_1}$ was diminished from 1·0 to 0·5.

* *Proc. Inst. Mech. Engineers*, October-December, 1919, p. 593.

TABLE IV.

$\frac{p_2}{p_1}$	0·5.	0·6.	0·7.	0·8.	0·9.	1·0.
α	0·98	0·98	0·97	0·96	0·94	0·91

It is of interest to compare Gibson's results with the curve of Fig. 29. The limiting value of α shown in the above table as $\frac{p_2}{p_1}$ approached unity was obtained by extrapolation of the experimental curve and does not, of course, represent an actual condition of flow, which must be zero when $\frac{p_2}{p_1} = 1$. We may therefore suppose without much error that Gibson's Venturi had a coefficient of about 0·92 (probably somewhat less) at a value of $\frac{p_2}{p_1}$ of 0·99. Now for this value of $\frac{p_2}{p_1}$, which, if p_1 be taken as normal atmospheric pressure, corresponds to a pressure difference $p_2 - p_1$ of about 4 inches of water (say 21 pounds per square foot), equation (7*a*) shows that the velocity at the throat of this particular Venturi was about 138 feet per second. Taking ν as 0·00016 we therefore find, since $d_2 = 1{\cdot}5$ inches $= \frac{1}{8}$ foot, the value of $\frac{v_2 d_2}{\nu}$ to be 108,000 approximately, so that $\log \frac{v_2 d_2}{\nu} = 5{\cdot}03$ and the value of α from Fig. 29 should be about 0·976. There is thus a discrepancy between Gibson's figures and those of Fig. 29. It should be noted, however, that the exit cone of the Venturi used by Gibson had a steeper slope than that commonly used. The expansion from $1\frac{1}{2}$ inches diameter at the throat to the full 3 inches diameter occurred in a length of $6\frac{1}{2}$ inches, which corresponds to an apex angle of the cone of 13°. This was almost certainly too large an angle for the cone to run full, particularly at the high throat speeds used in these experiments, and it is possible that this factor may have contributed to the relatively small value of α at the rates of flow at which the air could legitimately be regarded as incompressible. In the absence of further information no definite conclusion can be drawn, but the remarkable agreement obtained between different sets of experimental results in the derivation of the American curve of Fig. 29, and the fact that this method of correlating data rests on a secure theoretical basis, would seem to justify the practical application of this

curve, within the limits stated, to derive values of a in all cases of air flow where the highest accuracy is not required. In special cases a calibration of the Venturi in situ may be performed in the manner previously described for an orifice calibration. Gibson's results may be used to give an indication of the variation that may be expected in a with changes in the expansion ratio.

In order to deduce the discharge coefficient from Fig. 29 a knowledge is required of v_2, the throat speed, and ν. The former can be determined from equation (3*a*), treating the air as incompressible. This is only permissible if $\frac{p_2}{p_1}$ is not much different from unity, but it must be remembered that Fig. 29 only holds for incompressible flow, since it was derived from experiments with water, so that it cannot be relied upon to give good accuracy if $\frac{p_2}{p_1}$ is less than, say, 0·95. Values of ν for air in foot-pound-second units are given for a range of temperature in the following table :—

TABLE V.

Values of ν for Air.

Temperature. Deg. Cent.	Value of ν.	Temperature Deg. Cent.	Value of ν.
0	144×10^{-6}	40	185×10^{-6}
5	149×10^{-6}	50	196×10^{-6}
10	154×10^{-6}	60	207×10^{-6}
15	159×10^{-6}	70	218×10^{-6}
20	164×10^{-6}	80	229×10^{-6}
25	169×10^{-6}	90	240×10^{-6}
30	174×10^{-6}	100	251×10^{-6}

The pressure loss in a Venturi is appreciably less than that caused by an orifice, about 80 or 90 per cent. of the drop from entry to throat being ultimately recovered. (Compare Fig. 27.) Otherwise, the Venturi in its practical aspects presents much the same features as the orifice, and the remarks made under the latter heading regarding the relatively high pressures obtainable at low speeds, and the facility with which continuous records of flow can be taken, apply equally to the Venturi. As with the orifice plate, it is also important to have a sufficient length of straight pipe upstream of the entry.

The Shaped Nozzle.—The chief disadvantages of the plate orifice are the uncertainty that exists regarding the area of the vena contracta and the relatively large resistance it offers to the passage of air through it. Both these undesirable features

are, as we have seen, avoided by the use of a Venturi, but only at the expense of considerably increased cost and installation difficulties. The shaped nozzle, which is, in effect, a Venturi with the expansion cone removed, is a device intermediate between the two types of constriction hitherto considered. The unrecoverable loss of pressure through it is only slightly less than that through a plate orifice, and in this respect it is inferior to the Venturi. It possesses, however, the important feature of the latter that the jet at the section of low-pressure measurement is parallel and of an area equal to that of the minimum area of the constriction itself, since no subsequent contraction occurs. As regards cost and difficulty of installation it is superior to the Venturi, and only slightly worse than the plate orifice. Unless ease of installation and first cost are prime considerations, it is the author's opinion that in the

TABLE VI.

German Standard Nozzles. Dimensions in Millimetres.

Pipe Diameter.	Throat Diameter.	R.	r.	Length of Nozzle Proper.	Length of Cylindrical Portion.	Length and Diameters of Chamfer.			Nozzle Flange Thickness.
D.	d.			l.	l_1.	d_1.	l_2.	d_2.	t.
25	10	14	5	9	1	14	16	22	26
50	20	28	10	17	1	26	8	36	26
70	28	39	14	24	1	34	3	38	28
85	34	48	17	29	1	40	3	44	28
100	40	56	20	34	1	46	3	50	28
150	60	84	30	51	1	68	3	72	28
200	80	112	40	68	1	88	3	92	29
500	200	280	100	169	2	210	4	216	30
1000	400	560	200	338	3	410	5	416	30
1500	600	840	300	507	4	610	6	618	30
2000	800	1120	400	676	5	810	7	820	30
2500	1000	1400	500	844	6	1010	8	1020	30

majority of cases the shaped nozzle is the best form of constriction to use.

Two types of shaped nozzles are illustrated in Fig. 30. It will be seen that there is a curved entrance terminating tangentially in a direction parallel to the axis of the pipe. Some types have a short cylindrical throat at the end of the curved entrance, but this is found not to be essential, as, by properly shaping the curve, the fluid can be made to issue from the nozzle in a straight cylindrical jet without any parallel walls to guide it. The pressure drop through the nozzle is measured near the entry and at the throat, as shown in the

diagram, and the flow is calculated, as for a Venturi, by the use of equation (12). The discharge coefficient for a well-designed nozzle is about 0·95, varying somewhat with the design.

The nozzles illustrated in Fig. 30 have been standardised by the Association of German Engineers in their rules for the testing of fans and air-compressors. The thick plate type is used for small pipes up to 70 mm. (2·76 inches) in diameter, where weight is not objectionable, and the other (Fig. 30b) for larger pipes. The principal relative proportions are shown in the diagrams, and the leading dimensions for a number of pipe sizes in Table VI.

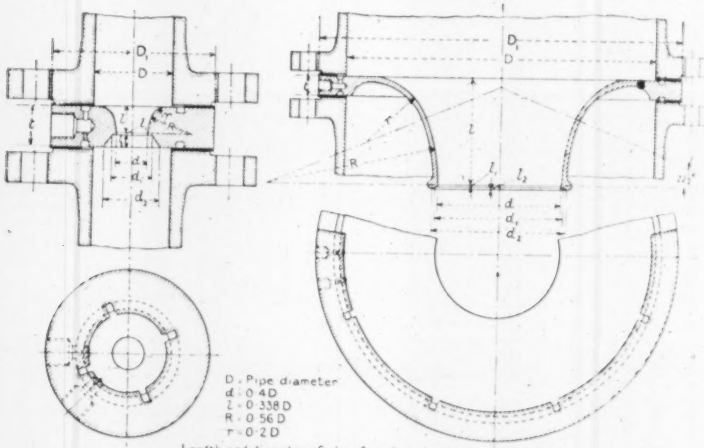

D - Pipe diameter
d = 0·4D
l = 0·338D
R = 0·56D
r = 0·2D
Length and diameter of chamfered protecting portion on throat varies with size of nozzle.
(a)
(b)

Fig. 30.—German standard nozzle.

Pressures are measured at the upstream and downstream faces of the flange of the nozzle, by means of pressure taps leading, as shown in Fig. 30, to annular grooves cut in the two faces of the flange. Between each pipe flange and the adjacent face of the nozzle flange is inserted a packing ring which covers and seals the annular pressure groove entirely, except at a number (4 to 20, according to the size of the nozzle) of places around the circumference, where slots cut in the ring put it in direct communication with the pipe static pressure at these points and so enable the mean pressure to be led to the manometer through the pressure tap connected to the ring.

The determination of the discharge coefficient of these nozzles formed the subject of a careful investigation by Jakob and Erk * who found that the coefficient was sensibly constant for values of $\frac{vd}{\nu}$ at the throat ranging from 71,000 to 377,000.

* *Forschungsarbeiten auf dem Gebiete des Ingenieurwesens*, No. 267, 1924, *Der Druckabfall in Glatten Rohren und die Durchflussziffer von Normaldüsen*, published by the Verein Deutscher Ingenieure.

The maximum drop across the nozzle in these experiments was $6\frac{1}{4}$ inches of water, so that equation (5) for incompressible flow could be used, the absolute pressure in the pipes being always approximately atmospheric. Since in this standard nozzle the ratio of the pipe diameter to the throat diameter is specified as constant for all sizes and equal to 2·5, it saves numerical work to obtain a value of the expression $\alpha \sqrt{\frac{r^2}{r^2 - 1}}$ instead of α only, and to call this the coefficient of the orifice. Expressing their results in this manner, Jakob and Erk found the coefficient within the above-mentioned range of $\frac{vd}{\nu}$ to have the mean value 0·96, whence, since r, the ratio of the areas, is 6·25, α for this nozzle becomes 0·948. Earlier experiments on this standard nozzle, in which the quantity of air flowing was measured by means of a calibrated gasometer, had indicated a coefficient of 0·97 to 0·995, but the various practical difficulties attendant upon this method of measurement (as, for example, the determination of the true mean temperature of the air in a large container such as that used, which had a volume of about 175,000 cubic feet) rendered the results not entirely satisfactory, and in presenting them it was stated that further tests were desirable. In Jakob and Erk's experiments the quantity was determined by measuring the pressure drop in suitable lengths of smooth calibrated pipes, a method which, as we have seen,* is capable of giving very good accuracy when the proper experimental conditions are observed.

An important feature of these experiments is that they included tests of the nozzles both with a length of pipe on the outlet side, and when placed at the end of the pipe line and discharging into atmosphere. Although the tests under each of these two conditions were sufficiently numerous to detect any difference in the discharge coefficient that might have existed, no such effect was found, and it may be accepted that the coefficient is the same in both cases. This result is of some practical importance, since it provides a ready means of measuring the quantity of air flowing in a small pipe (see p. 139).

A small number of tests was also made in which the nozzle was placed in a pipe of considerably greater diameter than the standard size for the nozzle. The discharge coefficient (as defined in these tests, viz. $\alpha \sqrt{\frac{r^2}{r^2 - 1}}$) was found to be 0·972. Now if α is the same for this type of nozzle irrespective of the size of the pipe in which it is installed, the quantity $\alpha \sqrt{\frac{r^2}{r^2 - 1}}$

* Compare Stanton and Pannell's experiments, p. 39.

will decrease as r increases, and will be equal to α, i.e. to 0·948, when r becomes very large—a condition corresponding to that of air discharging to atmosphere from a large chamber through a nozzle placed in the side. In a pipe larger than the standard size, therefore, Jakob and Erk should have found the value of their coefficient to be less than 0·96. In the conclusions to their papers, however, these experimenters do not seem to have attached much importance to this apparent discrepancy; they state that the value 0·96 for $\alpha\sqrt{\frac{r^2}{r^2-1}}$ may be adopted for these nozzles irrespective of conditions of installation, and regard the higher value obtained in the three tests made in larger pipes in the nature of an unexplained experimental error. The position does not, however, appear to be quite as satisfactory as this statement implies. There is no *a priori* reason why the discharge coefficient should be constant except for similar nozzles similarly installed, and whilst their conclusion as to the general applicability of the value 0·96 is probably sufficiently accurate for most purposes where the highest precision is not required, this value can only be regarded as definitely established for the case in which the throat diameter is equal to 0·4 times the pipe diameter. For this condition the coefficient may be accepted without hesitation, provided, as with the Venturi tube and the plate orifice, a sufficient length of straight pipe—say 10 diameters at least—precedes the entry to the nozzle. Further research on the value of the coefficient for ratios of throat to pipe diameters differing considerably from 0·4 would be of value, particularly if the tests were extended to include the limiting case of the discharge from large chambers, which is a measurement that frequently occurs in practice, and for which the use of a calibrated nozzle is the most convenient method.

One further characteristic of these nozzles, which, as we shall see later, is of some practical importance, deserves mention. Careful explorations of the issuing jet in a number of instances disclosed the fact that the velocity was practically constant over the entire section. It was only in the immediate vicinity of the walls that a slight falling off was observed. For all practical purposes the jet may be considered as having a uniform velocity equal to that measured by a single observation at the axis.

Mr. C. C. Fuller has been recently appointed manager of the Foxboro Company's New York Office. He replaces the late W. W. Patrick.

Mr. Fuller is already widely known in the Metropolitan Area and will therefore assume his new duties under highly favorable circumstances.

He will have complete charge and will be ably assisted by K. L. Barton, R. A. Rockwell and F. J. Leerburger.

Measurements

Industrial & Scientific

An Instruction Book for Engineers

DR. WALTER BLOCK

Eichungsdirektor der Provinz Ostpreussen

CHAPTER VIII. MEASUREMENT OF VOLUMES

THE determination of the space which is occupied by a body necessitates methods which depend quite essentially on whether the body is solid, liquid, or gaseous. This problem moreover, can easily be solved indirectly, by considering that the volume v of a body, its mass m, and its density d are related mathematically by the simple formula $d = v/m$. The determination of density, a very important physical quantity, will be discussed later in a separate chapter. It may suffice to mention here that the latter can, in many cases be determined very easily, or be considered as given *a priori*. In such cases, therefore, a simple weighing is sufficient in order to determine from this, the volume of a body. Similarly, such weighing, in connection with a determination of volume, suffices for the calculation of the density of a body. In other words, the problem of the determination of a special quantity is very closely connected with the determination of density, consequently the methods for measuring these two quantities are, to a certain extent, entirely similar and difficult to separate.

1. Solid Bodies

The volume of a solid body can in many cases be determined without special methods by simple measurements of dimensions if the body has a convenient shape. For the formulas of simple bodies, refer to mathematical handbooks.

The problem is, however, much more difficult if the body has an irregular shape so that linear measurements cannot be made. In this connection another circumstance maybe discussed which is of importance in certain cases, that is whether the body fills its space completely or whether it can be designated as porous. In this case, one must distinguish between the volume of the body so defined that all its surface pores are considered closed, and the volume of the body if the space of its pores be subtracted. These two volumes are two quantities which are naturally entirely independent of each other and altogether different, and which, therefore, have to be taken into account when measuring. A brief outline of how one is to proceed in such a case may suffice: In the former case if there is reason to believe the body be porous, it will often be possible to immerse the body in hot paraffin or similar substances, or to cover it with a thin lacquer, to seal its surface pores. Methods of hydrostatic weighing, to be discussed later, can then be employed directly without fear that water will penetrate into the body and falsify the result. In the other case, if the body is porous and the volume of the pores is not to be taken into account, there exists in many cases the possibility of triturating the body as finely as possible; compressing the powder tightly and then measuring its volume. In a hydrostatic weighing the result can also be arrived at if the body is

first weighed perfectly dry and then in water as soon as one has the assurance that the latter has penetrated completely into all cavities and that no hollow spaces remain which could cause buoyancy due to enclosed air. A body can be filled with liquid quite easily if it is brought into the liquid in a closed vessel which can be evacuated, that is where the air can be removed by an air pump, by boiling out, etc.

It is self-understood that the loss of weight which a body suffers in the hydrostatic methods by immersing in the liquid can be due only to the body itself if its pores are completely filled with the same liquid. For the hydrostatic method water is mostly employed. But porosity of the body, if volume of the pores is to be determined, may be the reason for using, instead of water, very fluid and volatile liquids, in order to be able to remove them again more conveniently from the body. Such liquids are benzene, ether, etc., and their density, of course, must be determined in each individual case and considered in the calculation. In other cases, as when employing mercury, one has the advantage that it does not penetrate at all into the pores so that it is not necessary to coat the body, and thus the total volume can be determined, directly. The use of mercury will, however, be precluded in many cases because most bodies do not sink into it sufficiently, and it is therefore unsuitable for hydrostatic weighing.

Several special methods may now be discussed which permit determining the volume of a body with sufficient accuracy. First, may be discussed the method involving the use of the pycnometer, the various forms of which will be treated in detail in the chapter on measurement of density. This method can be used only if the body can be broken into small pieces, as it has to be passed through the neck of the pycnometer which, for obvious reasons, must be kept narrow. The method is as follows: As is known, the pycnometer is a little bottle with a mark on its neck defining its volume. The pycnometer is first filled with water up to the mark and weighed, which gives the weight m. Then the substance, the volume of which is to be determined, is placed in it; again filled with water up to the mark and weighed, which gives weight m'. The body alone may have weight p; the formula for the calculation of its volume is then the following: $v = m + p - m'$.

The method only gives satisfactory values if the pycnometer is fairly well filled by the body so that its weight, compared to that of the replaced water, is of importance. Otherwise no satisfactory results can be expected. The following gives an idea of the degree of accuracy which can be obtained.

Given a pycnometer with a volume of 50 cc. and a mineral of density 2 to be determined. The empty weight of the pycnometer is 20.000 g. 1.000 g. of the body is brought into the bottle, that is a volume of 0.500 cc. Then

$$m = 20.000 + 50.000 = 70.000 \text{ g.}$$
$$m' = 20.000 + 49.500 + 1.000 = 70.500 \text{ g.}$$
$$p = 1.000.$$
$$v = 70.000 + 1.000 - 70.500 \text{ g.} = 0.500 \text{ cc.}$$

If for each weighing a possible error of 1 mg. is now admitted, the greatest error in the volume will be 3 mg. in 500 mg. $= 3/500 = 0.006$.

Now, instead of 1 g. we place 80 g. or 40.000 cc. in the pycnometer then

$$m = 20.000 + 50.000 = 70.000 \text{ g.}$$
$$m' = 20.000 + 10.000 + 80.000 = 110.000.$$
$$p = 80.000.$$
$$v = 70.000 + 80.000 - 110.000 = 40.000.$$

The accuracy is now $3/40000 = 0.00007$.

Instead of water, another liquid of known density may be employed the determination of which will, in general be easy if, besides filling the pycnometer with this liquid a determination is also made by filling with water.

The principal method, which in almost all cases produces the desired result, and is inapplicable only if the body cannot be brought into contact with liquids, is hydrostatic weighing, which is based on the Archimedes principle: that a body immersed into a liquid loses a weight equal to that of the liquid which it displaces. The same method serves with good accuracy for the determination of density of solid bodies and for this reason it may be discussed somewhat more in detail while otherwise the reader may be referred to the chapter on determinations of density.

In practice, one proceeds in the following manner: the body is weighed by any usual method and then suspended on a fine wire on the pan of the balance. (Whether it is fastened above the pan on a hook or suspended from the pan itself is after all a matter of the construction of the balance, according to where the container for the liquid can be placed.) The body is then arranged to hang from the balance into the liquid, usually water, with the wire on which it is suspended and which, by the way, can also be replaced by a little basket into which the body is placed. The liquid is placed below the pan in a larger container or on a small bench above the pan proper. Then the weight of the body in the water is determined — from which, of course, must be deducted by another weighing the weight of the suspension wire in water. This multiple weighing can be eliminated fairly simply by giving the wire a proper shape and taking care from the beginning that the wire is already immersed in water when the weight of the body is measured out of the water. In other words, the procedure for weighing in water should be fully prepared except that the body is not yet in water but resting free on the balance. Care is then to be taken that in both cases the water has the same level, because if the body is placed in the water, the level will naturally rise and more of the wire will be submerged, which would slightly falsify the result. The simple calculation follows:

If m is the weight of the body in air, m' that in a liquid of density d, then $m-m'$ is the loss of weight which must be equal to the weight of the replaced liquid. If v is the volume of the body and therefore of the liquid then $m-m'=v \cdot d$, and $v=\dfrac{m-m'}{d}$. For water d is presumably equal to unity.

In practice, the wire renders the weighing a little more difficult if the body is comparatively small, because of the meniscus effect where the wire pierces the surface of the water. Water is particularly unfavorable in this respect, but good results can be obtained if care is taken that the wire be as thin as possible and fully free of grease. When possible better results can be obtained if the wire is surrounded by a little glass tube filled with oil. The main thing is not to have the wire heavier than required. Platinum wire is generally used, and if one considers that a platinum wire of 1 mm.^{2} section can carry 30,000 g. one can figure the size of wire to use. The table herewith gives the maximum carrying capacity for different diameters. Care must, of course, be taken not to exceed the loads.

CARRYING CAPACITY OF WIRES OF DIFFERENT DIAMETER WITH A CARRYING CAPACITY OF 30 KG. FOR 1 MM.² (PLATINUM)

mm. diameter	kg.	mm. diameter	g.
1	23.5	0.2	930
0.9	19.1	0.1	235
0.8	15.0	0.08	150
0.7	11.5	0.05	59
0.6	8.5	0.02	9
0.5	5.9	0.01	2
0.4	3.8	0.005	0.5
0.3	2.1		

In case the weighing in water is made afterwards a meniscus correction has to be made, the weight of the water adhering to wire can, with sufficient accuracy, be assumed as $7 \pi D$ = approx. 21D in milligrams where D is the diameter of the wire in millimeters. For other details the chapter on measurements of density may be referred to.

2. Chemical Measuring Devices

The problem of the determination of volume of liquids is incomparably more important in chemistry and shall therefore, be treated in greater detail. For routine work the chemist is already acquainted with a great variety of measuring apparatus. Volumetric flasks, bottles, burettes and similar measuring apparatus may be alluded to, which permit either the measurement of definite amounts of liquid in prescribed quantity, or, generally, to determine what volume is occupied by certain amounts of liquids. Most of these devices are supplied commercially fully graduated and the industry has been so far developed that these graduations can be relied on, except in very cheap grades. A great number of devices can be calibrated at the Physikalish Technische Reichsanstalt with considerable accuracy. It is not amiss therefore, to indicate what degree of precision can be obtained in these tests by the Physikalich Technische Reichsanstalt, because these very figures also give an idea of the accuracy obtainable in the use of such measuring apparatus. First, the rules of the Reichsanstalt may be discussed briefly. For one specific test are submitted measuring apparatus without divisions, giving one single definite quantity. In this category belong flasks, cylinders with one limiting mark, pipettes, also for one quantity only, pycnometers, dilatometers, etc. Next are admissible apparatus with a greater number of marks; and finally apparatus with divisions, as measuring bottles and cylinders, burettes of all kinds, measuring pipettes and measuring tubes. All these apparatus are officially checked for contents in liters or cubic centimeters, i. e., for the space which 1 kg. of pure water occupies under known standard conditions. Equivalent to this is the cubic decimeter (see Introduction). No distinction between cubic decimeter and liter, therefore, is made. Considering that the spatial capacity of all such containers depends greatly on their own temperature, they must all have the standard temperature indicated on them. For this, various values between 0 and 25°C. are in use. Generally, 20°C. is now usual.

The spatial capacity of such measuring apparatus depends to a certain extent on how they are used. If they are originally dry, a certain quantity of liquid can be filled into them up to their limiting mark, (working by filling-up). If this quantity of liquid is poured from the container (working by pouring) a somewhat smaller quantity of liquid will be obtained as, of course, a little will stick to the walls of the container. This remaining quantity is determined not only by the kind and cleanliness of the con-

tainer wall but also by the kind of liquid. Therefore, slightly less accuracy may be expected when working with pouring because the remainder will vary somewhat. Official regulations tell how one must proceed in order to obtain the highest possible accuracy in working by pouring. Measuring apparatus with a lip should be tilted gradually when pouring until almost horizontal. Waiting half a minute (or a time given on the container) after the continuous flow has ceased the lip is wiped off on the container just filled. Measuring apparatus with a run-off are operated by letting them run out in vertical position, burettes freely, others by holding the running-off end in contact with the wall of the container to be filled. The run-off end of pipettes is wiped off on the top of the container to be filled one-quarter minute after complete emptying, of burettes one-half minute. The adjustment and also the reading, are made during the wiping. As is known, liquid surfaces are not a straight line in all these containers, but slightly curved. The reading is always taken at the lowest point; always at the highest point for non-moistening liquids such as mercury, and on the edge for opaque liquids only.

Graduated flasks can have contents up to 10 liters, cylinders up to 5 liters. In order to obtain sufficient accuracy in reading, the neck of flasks and cylinders at the place of measuring must not exceed certain diameters. For this the figures given in the tables below are prescribed. For pipettes a definite running-out time should be kept which is also given in the tables. Pycnometers are admitted up to 250 cc. The divisions on graduated apparatus must be so that two adjacent lines have a distance of at least 1 mm. The contents of the measures must be given in liters, milliliters, or cubic centimeters. Milliliters and cubic centimeters are, after what has been said before, to be considered equivalent. Further, the standard temperature must be given on the measuring devices, and also, if this is not self-understood, whether the apparatus operates by filling-in or pouring-out. Such apparatus as can be used both ways must show corresponding indications. It is, of course, self-understood that a flask for one liter which is to be used for both filling and pouring, must have two marks of which the one for pouring has to be a little higher, as a little more than one liter must be filled in if exactly one liter is to be obtained by pouring. An ultimate waiting time must also be indicated. Full-pipettes of more than 250 cc. have the same errors as those for flasks of equal size, the full-pipettes for filling half the error of the full-pipettes for pouring. If pycnometers have movable parts, such as stoppers of insertion thermometers, no greater uncertainties must occur due to different inserting of these parts than necessary by the conditions.

Calibrating Rules for Chemical Volumetric Apparatus for Liquids

Widths of Necks at the Point of Measurement

Size from		25	50	200	500	1000	1500	2000	3000	4000	5000 cc.
To	25	50	200	500	1000	1500	2000	3000	4000	5000	10000 "
Not more than	6	10	12	15	18	20	25	30	35	40	50 mm.

Width of Measuring Cylinders

Size from		50	100	300	600	1000	1500	3000	4000 cc.
To	50	100	300	600	1000	1500	3000	4000	5000 "
Not more than	22	30	40	50	60	70	80	90	100 mm.

Running-out Time for Full-Pipettes

Size from		10	50	100	250	500	1000	cc.
To	10	50	100	250	500	1000	2000	"
Running-out time	15—20	22—30	32—40	45—60	65—90	90—120	130—180	sec.

Running-out time for burettes and measuring pipettes for different lengths of division (for water)

Length from		20	35	50	70	cm.
To	20	35	50	70	100	"
Running-out time	25—35	35—45	45—55	55—70	70—90	sec.

LIMITS OF ERROR

Flasks for filling:

Size from		10	25	50	100	250	400	600	1000	1500	2000	3000	4000	5000 cc.
To inclu.	10	25	50	100	250	400	600	1000	1500	2000	3000	4000	5000	10000 "
Limits of error	0.008	0.015	0.02	0.15	0.08	0.11	0.14	0.18	0.25	0.35	0.5	0.8	1.2	2.0 "

Delivery flasks twice the above limits of error

Cylinders for filling:

Size from		30	50	100	200	400	600	1000	1500	2000	3000	4000 cc.
To	30	50	100	200	400	600	1000	1500	2000	3000	4000	5000 "
Limits of error	0.06	0.10	0.20	0.5	1.0	1.5	2.0	2.5	3.0	4.0	6.0	9.0 "

Delivery cylinders twice the above limits of error

Full pipettes for:

Size from		2	5	10	20	30	50	100	150 cc.
To	2	5	10	20	30	50	100	150	250 "
Limits of error	0.006	0.01	0.015	0.02	0.025	0.035	0.05	0.07	0.08 "

Full pipettes over 250 cc. same limits of error as corresponding filling flasks.

Full pipettes for filling half the above limits of error.

Pycnometers and similar apparatus

Size from		10	25	50	75	100	150	200 cc.
To	10	25	50	75	100	150	200	250 "
Limits of error	0.003	0.005	0.008	0.010	0.012	0.015	0.020	0.025 "

APPARATUS WITH GRADUATIONS

Measuring glasses for filling

Size from		5	10	30	50	100	200	400	600	1000	1500 cc.
To	5	10	30	50	100	200	400	600	1000	1500	2000 "
Limits of error	0.02	0.03	0.05	0.08	0.15	0.40	1.0	1.5	2.0	2.5	3.0 "

Delivery measuring glasses twice the above limits of error

Burrettes, measuring pipettes, etc.

Size from		2	10	30	50	75	100	150	200	250 cc.
To	2	10	30	50	75	100	150	200	250	300 "
Limits of error	0.008	0.02	0.03	0.04	0.06	0.08	0.10	0.12	0.14	0.18 "

The error of the volume enclosed by two marks must not be greater than half the admissible error for the total volume if the partial volume does not amount to half of the total volume. If the partial volume is greater its error may be the full amount of the error for the total volume.

Concerning the question of standard temperature, the following must be pointed out: The quantities indicated on a measuring device are valid only for the respective standard temperature. If one works at a different temperature, the volumetric capacity of the container changes. The glass used almost exclusively for these containers (the so-called Thueringen glass to which also the usual apparatus glass can be considered equivalent) has a linear expansion coefficient of about 8×10^{-6}. The volumetric expansion coefficient is three *times* the linear coefficient. That means that a liter flask increases its volume for a temperature increase of 1°C. by $3 \times 8 \times 10^{-6}$, that is about 25 mm.^{3}, larger or smaller containers correspondingly. The following table gives a short tabulation of the changes in volume of glass measures at different temperature changes and will be fully sufficient to calculate eventual changes.

Change in Colume of Glass Apparatus with Temperature Changes

Contents	10 l.	5 l.	2 l.	1 l.	500 cc.	200 cc.	100 cc.	50 cc.	20 cc.	10 cc.
Temp. Change °C	cc.	cc.	cmm.	cmm.	cmm.	cmm.	cmm.	cmm.	cmm.	cmm.
1°	0.25	0.125	50	25	12.5	5	2.5	1.25	0.5	0.25
2	50	0.25	100	50	25.0	10	5.0	2.50	1.0	0.50
3	75	0.375	150	75	37.5	15	7.5	3.75	1.5	0.75
4	1.00	0.50	200	100	50.0	20	10.0	5.00	2.0	1.00
5	1.25	0.625	250	125	62.5	25	12.5	6.25	2.5	1.25
6	1.50	0.75	300	150	75.0	30	15.0	7.50	3.0	1.50
7	1.75	0.875	350	175	87.5	35	17.5	8.75	3.5	1.75
8	2.00	1.00	400	200	100.0	40	20.0	10.00	4.0	2.00
9	2.25	1.125	450	225	112.5	45	22.5	11.25	4.5	2.25
10	2.50	1.25	500	250	125.0	50	25.0	12.50	5.0	2.50
20	5.00	2.50	1000	500	250	100	50	25.0	10	5.00
30	7.50	3.75	1500	750	375	150	75	37.5	15	7.50
40	10.00	5.00	2000	1000	500	200	100	50.0	20	10.0
50	12.5	6.25	2500	1250	625	250	125	62.5	25	12.5
60	15.0	7.50	3000	1500	750	300	150	75.0	30	15.0
70	17.5	8.75	3500	1750	875	350	175	87.5	35	17.5
80	20.0	10.00	4000	2000	1000	400	200	100.0	40	20.0
90	22.5	11.25	4500	2250	1125	450	225	112.5	45	22.5
100	25.0	12.50	5000	2500	1250	500	250	125.0	50	25.0

3. Determination of Volume of Vessels by Weighing

In the following, there will now be discussed in more detail how such measures can be calibrated by one who is not in position to use officially calibrated vessels. Considering the difficulty of this task, the ordinary proving stations[1] are not in position to carry out such examinations. In general, there are only two calibrating stations,[1] beside the Physikalisch-Technische Reichsanstalt, equipped for calibrating these apparatus. It may be said at the outset that of course such examinations are carried out according to weighing methods and, therefore, a set of weights must be used which has to be correct as explained before, that is, which has to give the true weights within the required limits of error. The usual analytical sets of weights or other equivalent ones, generally do this with sufficient accuracy.

The customary method, followed also by the calibrating stations, which has proved to be the most convenient, is the following: Assume we want to check a flask with nominal contents of one liter. We place this flask on the one side of the balance together with a weight of 1 kg. (1 kg. water = 1 l.) and tare this load on the other side of the balance with any other weights. After this, the one kg. weight is removed from the scale and the flask filled carefully with distilled water of determined temperature. If this flask is correct then it is obvious that the filling with water must, apparantly, be lighter than corresponding to the kilogram weight. To a correct flask a certain addendum must, therefore, be put on the scale to obtain equilibrium. This addendum can be calculated directly from the constants of the air, that is, the pressure and temperature of air which have to be taken into consideration in any case. If one works at the normal temperature of the flask it is possible to determine the addition directly from this. The actual addition which is necessary to obtain equilibrium of the scale, minus the calculated addition, immediately gives the error of the flask. If the flask is smaller than its nominal value, more has to be added; if it is greater, less. With greater deviations upwards the addition will even have to be placed on the side of the tare.

If one does not work at the normal temperature, conditions become a little more complicated. If, for instance, we work at a higher temperature, it has to be taken into account that the flask has expanded and consequently contains more water, and correspondingly the addition for higher temperatures should be smaller. But at the same time, with higher temperature the density of the water also has changed, which has to be taken into account even in case the flask temperature is normal. Due to this change of density of the water, less weight can be put in the flask which, in its turn, increases the addendum. We will now determine, by an example, how conditions are in reality, and how the addendum can be calculated in a simple case. If one has to carry out such work more often it would be, of course, unnecessary trouble to make this whole calculation in each individual case. It is simpler to get the very convenient and very exhaustive tables published by the Physikalisch-Technische Reichsanstalt, Department I for Weights and Measures (the former Normal-Eichungskommission) which contain the exact values of the addendum for all cases of the usual sizes. From these, the nominal addendum can be taken without difficulty, not only for the normal temperature but also for temperatures differing

[1] In Germany.

from it so that the value of the nominal addendum is given directly, and the difference from the actual addition then indicates directly the error of the measure.[2] In order to get an approximate idea the following figures may be given: one liter made of glass, correct at 0°, is larger, at the temperatures of 15°, 17.5°, and 20°C, by the following amounts (see above table):

375 mm.^{3}, 438 mm.^{3} 500 mm.^{3},

whilst one liter of water which, at 0°C., is exactly one liter, is greater after heating to the same temperatures by the following amounts:

742 mm.^{3}, 1157 mm.^{3}, 1641 mm.^{3}.

Consequently, water which in an accurate glass container at 0° occupies the space of one liter, at this temperature is apparently more voluminous at the above three temperatures by the following amounts:

$742-375=\ 367$ mm^3,
$1157-438=\ 719$ mm^3,
$1641-500=1141$ mm^3.

Now, if we want to calculate quite generally what addenda are necessary with this weighing method we will start with a special example. Let us assume that we work with water of 18.5° and at the same air temperature and an atmospheric pressure of 756 mm. That means that the weight of 1 cc. air is just 1.200 mg. In the same manner we can take from known tables that the density of water at this temperature is 0.998528. We have a flask of 1 liter nominal contents. The latter is placed on the scale with a brass weight of 1 kg. of a density of 8.4 (this figure is usually assumed) and balanced. The weight has a volume of $1000/8.4=119$ cm^3. If we, therefore, remove at the second weighing the kilogram piece and fill the flask with water the buoyancy of the air does not then act on these 119 cc. but on 1000 cc. The difference is 881 cc. The filling with water is therefore apparently lighter by the amount of $881 \times 1.200 = 1058$ mg. because of the buoyancy of the air. In order to create equal conditions we have to add right from the beginning 1058 mg. to equalize the difference in the air buoyancy. A correct liter flask at 18.5° has now increased its volume over that at 0° by 462 mm^3. (see above table), it can therefore contain 462 mg. water more than corresponds to its nominal value; this number of mg. must be removed from the scale. But, further, 1 liter of water at 18.5° does not weigh 1 kg. but 0.998528 kg. For this reason a third addition of 1472 mg. is necessary. Therefore, the following three addenda are required:

due to buoyancy of air	+1058 mg.
due to expansion of glass	− 462 mg.
due to density of water	+1472 mg.
	+2068 mg.

This is the addendum which would be required for a flask correct at 0°C, to balance it under the conditions given above. If actually an addendum of 3000 mg. is required that means that the crucible contained too little water, it is too small by 932 mg. = 932 mm^3. If an actual addendum of only 1000 mg. were required it would be too large by 1068 mm.^{3}, but if 1000 mg. had to be placed on the side of the weights, it would be too large by 3068 mm^3.

[2]Similar tables are also contained in quite a few treatises and hand-books, particularly those on volumetric analysis.

Table to Determine Volume of Glass Containers from the Weight of Water to fill them for a rated volume of 1 liter at 0°C.

I. Value of addition in milligrams, in relation to the water temperature and glass temperature.

Temp. °C.	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
10	23	30	37	44	51	58	65	72	79	86
11	93	101	109	117	126	133	141	149	158	167
12	176	185	194	203	212	221	231	241	251	261
13	271	281	291	302	313	324	335	346	357	368
14	379	391	403	415	427	439	451	463	475	487
15	499	512	525	538	551	564	577	590	603	617
16	631	645	659	673	687	701	715	730	745	760
17	775	790	805	820	835	850	866	882	898	914
18	930	946	962	978	994	1011	1028	1045	1062	1079
19	1096	1113	1130	1147	1165	1183	1201	1219	1237	1255
20	1273	1291	1309	1327	1346	1365	1384	1403	1422	1441
21	1460	1479	1498	1518	1538	1558	1578	1598	1618	1638
22	1658	1678	1698	1719	1740	1761	1782	1803	1824	1845
23	1866	1887	1909	1931	1953	1975	1997	2019	2041	2063
24	2085	2107	2129	2152	2175	2198	2221	2244	2267	2290
25	2313	2336	2359	2383	2407	2431	2455	2479	2503	2527
26	2551	2575	2599	2623	2648	2673	2698	2723	2748	2773

II. Correction in milligrams to add due to air pressure and air temperature

Temperature °C. \ Barometer mm.	680	690	700	710	720	730	740	750	760	770	780
10	981	995	1009	1023	1037	1051	1065	1080	1095	1110	1125
11	977	991	1005	1019	1033	1047	1061	1076	1091	1106	1121
12	974	988	1001	1015	1029	1043	1057	1072	1087	1102	1117
13	970	984	998	1012	1025	1039	1053	1069	1083	1098	1113
14	967	981	994	1008	1022	1036	1050	1065	1079	1094	1109
15	963	977	990	1004	1018	1032	1046	1061	1075	1090	1105
16	959	973	987	1001	1014	1028	1042	1057	1071	1086	1101
17	956	970	983	997	1010	1024	1038	1054	1067	1082	1097
18	952	966	979	993	1007	1021	1035	1050	1064	1078	1093
19	949	962	976	990	1003	1017	1031	1046	1060	1074	1089
20	945	959	972	986	999	1013	1027	1042	1056	1070	1085
21	941	955	968	982	995	1009	1023	1039	1052	1066	1081
22	938	951	965	979	992	1006	1020	1035	1048	1062	1077
23	934	948	961	975	988	1002	1016	1031	1044	1058	1073
24	931	944	957	971	983	998	1012	1027	1040	1054	1069
25	927	940	954	967	980	994	1008	1023	1036	1050	1065
26	924	937	950	963	977	991	1005	1019	1033	1047	1061

In the foregoing tables, the calculations are generally on the same basis as in the foregoing special case. The tables indicate, therefore, by the summation of their partial values, the nominal addendum which is required for a glass flask the nominal value of which is just 1 liter. If the actual addendum has to be greater it means that it contained less water that is, it was actually too small, and vice versa.

The table holds good for a normal temperature of 0°C., and if the flask is determined for another normal temperature its error can be converted to another temperature by means of the table in Section 2.

The figures are only good for the size of 1 liter. For other sizes, the corresponding fractions or multiples of the correction have to be calculated. The following examples will very likely sufficiently illustrate the use of the table. They also deal with the case of a glass container of quite irregular shape to be measured, the volume of which has first been quite roughly determined in another way.

Examples: 1. Flasks, 1 liter nominal contents. Water temperature 13.3°C., air temperature 16.0°C., barometer 762 mm., normal temperature of the flask 15°C.

Correction I + 303 mg.	Addendum found +1720 mg.
Correction II +1074	Flask at 0° therefore too small by 343 mg.
———	Expansion of the flask (0–15°) (from table) 375 mg.
1377 mg.	Flask too large at normal temperature by 21 mg.

2. Pipettes: Nominal value 220 cc. water temperature 19.8°, air temperature 23°, barometer 750 mm., normal temperature 20°.

Correction I +1237	Addendum found +510.
Correction II +1031	Pipette therefore too small at 0° by 56 mg.
	Expansion of pipette (0–20°) (see table) 100 cc.
2268 for 1 l.	Pipette at 20° too large by 44 mg.

for 220 cc. = 454

3. Flasks: Contents determined by rough measurement to be about 800 cc. Water temperature 18.1°, air temperature 17°, barometer 765 mm.

Correction I + 946	Addendum found −5834 mg.
Correction II +1074	Crucible too large by 7450 mg.
	True value at 0°, therefore, 807.45 cc.
2020 for one liter	

for 800 cc. = 1616 mg.

The tables given above will perhaps be useful in many cases and generally sufficient for the weighing of glass apparatus. It is, of course, possible in exactly similar manner to compile corresponding tables for containers of other materials. It would, however, lead too far to discuss this in greater detail. It may be said briefly how conditions change if other materials are employed. We will make up such a table for iron with the linear expansion coefficient of 11×10^{-6}, brass of 19×10^{-6}, and quartz glass of 0.5×10^{-6}.

Auxiliary Table III for Apparatus of Iron, Brass and Quartz Glass with Rated Content of 1 liter

Temp.°C.	Iron	Brass	Quartz glass	Temp.°C.	Iron	Brass	Quartz glass
10	− 57	− 297	+ 258	18	786	354	1353
10.5	− 28	280	303	18.5	863	420	1446
11	+ 5	259	353	19	944	488	1543
11.5	+ 40	235	403	19.5	1027	560	1642
12	+ 80	208	458	20	1113	633	1743
12.5	121	180	516	20.5	1201	710	1848
13	177	145	577	21	1292	788	1954
13.5	225	108	641	21.5	1386	871	2064
14	267	69	708	22	1482	954	2175
14.5	321	− 26	778	22.5	1581	1042	2290
15	379	+ 19	852	23	1682	1130	2407
15.5	439	68	928	23.5	1786	1223	2527
16	503	119	1007	24	1893	1317	2649
16.5	569	174	1090	24.5	2001	1414	2774
17	639	231	1175	25	2113	1513	2901
17.5	711	292	1263	25.5	2226	1615	3030
				26	+2343	+1719	+3162

Example: The capacity of a container of brass of a nominal volume of 1 liter is to be determined in the same manner as described. The measure is balanced with a plane glass plate one side of which is frosted, and a weight of 1 kg., then, after removing the weight, it is filled with distilled water so high that the glass plate (frosted side downward), covers the filled measure so that no air bubble remains.

Water temperature 12.5°, air temperature 17°, barometer 765 mm.

Correction I (from table I) − 180	Observed addition 250 mg.
Correction II (from table II) +1074	The measure is too large by 654 cc.
894 mg.	

Finally, we may discuss briefly how one proceeds in such cases with slightly less accuracy, as one wants to evaluate glass vessels without taking into account the exact values of all corrections but operating only with average values. In that case, the following table can be used to advantage, which works with an average air density and takes only into account those corrections which occur if the water changes its volume with temperature.

Table for Weighing Glass Vessels with Low Accuracy

(One must distinguish between "true" weight, weight in vacuum, and "apparent" weight, weight in air of density 0.0012. A "true" brass gram, density 8.4, therefore volume 1/8.4 = 0.119 cc., has therefore an apparent weight of 1 g. − 0.119 x 1.2 mg. = 1 g. − 0.143 mg. For water, the apparent weight of 1 g. is, similarly: 1 g. − 1.000 x 1.2 mg. = 1 g. − 1.200 mg.

Therefore, one "apparent" brass gram (that is the actual g.-weight of a set of weights) is equal to 1 g. −0.143 mg., one "apparent" g. water 1 g. +(1.200 −0.143) mg. =1 g. +1.057 mg. =1.001057 g. "true" g. of water. For instance, water of 18° has the density 0.998622, therefore 1 g. water weighed with brass in air of a density 0.0012, occupies a space $\frac{1.001057}{0.998622}=\frac{1.001057}{1-0.001370}=1.002435$ cc. Accordingly, the following table holds good:

Temp.	WEIGHT 1	2	3	4	5	6	7	8	9
10°	1.0013	2.0027	3.0040	4.0053	5.0066	6.0080	7.0093	8.0106	9.0120
1	14	28	43	57	71	85	99	114	128
2	15	31	46	61	76	92	107	122	138
3	16	33	50	66	82	99	116	132	148
4	18	36	54	72	90	107	125	143	161
5	19	39	58	77	96	116	135	154	174
6	21	42	63	84	104	125	146	167	188
7	23	45	68	90	113	136	158	181	203
8	24	49	73	98	122	146	171	195	220
9	26	53	79	105	132	158	184	210	237
20	28	57	85	113	142	170	198	226	255
1	30	61	91	122	152	182	213	243	274
2	33	65	98	130	163	196	228	261	293
3	35	70	105	140	174	209	244	279	314
4	37	75	112	150	187	224	262	299	337
5	40	80	120	160	200	240	280	320	360
26	43	85	128	170	213	256	298	341	384

For other weights, the above figures are to be taken as corresponding multiples.

Example: The capacity of a glass flask has been determined, without any correction, by weighing with water of 20° to be 784.9 g. what is its volume at 20°?

700 g.	701.98
80	80.226
4	4.0113
0.9	0.90255
	787.12 cc.

For conversion to another temperature compare table in Section 2 of this chapter.

However, the problem discussed above, of determining the volume of containers with greater accuracy, has not been treated quite completely. We have assumed in the foregoing example that we know the nominal capacity of the vessel with fair approximation, and that we therefore can determine directly how we balance this nominal capacity by the first additional weight. This solution fails therefore where a volume must be determined which is wholly unknown. In this case we can in fact proceed in exactly the same manner but of course, the approximate volume has to be determined before by weighing. This value is used as a starting point and one works further with it without consideration that it has made a larger error, in which case the addendum eventually becomes very large so that its buoyancy can no longer be entirely neglected. One has to be satisfied in this case with a somewhat lesser accuracy or the comparatively simple method must be repeated with a corrected value of the principal weight. The amount of the addendum can in all cases be taken without difficulty from the foregoing tables.

The foregoing problem of determination of the volume of containers by weighing with water is, however, not yet quite complete, particularly if it is a question of determining smaller volumes with sufficient accuracy. This holds good in the case of pycnometers or similar containers, especially also for pipettes and finer burettes. It must also be observed that the filling with water is somewhat difficult if the water has to come up to definite marks because, as water moistens the glass wall very badly, it is difficult, even with the greatest cleanliness, to fill with certainty to the proper mark. Besides, if smaller vessels with narrow tubes in which water must

be adjusted are to be evaluated, very sensitive scales are required, as in this case noticeable deviations from the accurate balance of the scale would not cause a noticeable change of weight in them. In such cases it is therefore more advantageous not to use water but to weigh preferably with mercury. This offers certain advantages, among them the following:

The temperature determination which is not always convenient when using water, is comparatively simple with mercury because it has an appreciably higher heat conductivity than water. The glass wall of the container has a very low heat conductivity and the equalization of temperature with the surroundings takes place very slowly; also, of course, in the case of a container placed in a bath. In this case, mercury is more advantageous because it assumes a uniform temperature more rapidly than water. For such case, of course, the same tables can be computed as before but generally this will not be done as this work seldom occurs and is limited generally to the measurement of very small quantities. But in order to have the necessary experimental basis the fundamental density values of mercury may be tabulated in the following as far as they will generally be required, and it may suffice to give one example of how one proceeds. Given a pycnometer of about 5 cc. cubic contents which has been determined, by the usual weighing methods, when filled with mercury to 67.513 g. The mercury has a temperature of 17.3°, and this may also have been the temperature of air while the barometric pressure was 753 mm., the whole calculation is then the following:

Specific Gravity of Mercury

Temp.	0	1	2	3	4	5	6	7	8	9
10	13.5698	13.5683	13.5658	13.5637	13.5609	13.5584	13.5560	13.5535	13.5511	13.548
20	461	437	412	388	363	339	314	290	265	241
30	216	191	167	142	118	094	069	045	020	4996

Weighing of a Pycnometer with Mercury

Filled weight 67.513 g., temperature of filling 17.3°, density of mercury therefore 13.5528. Air pressure 753 mm. at 17.3°. Air density therefore 0.001200.[4]

[4]See chapter on weighing.

Volume of weights 67.5/8.4 = 8.04 cc., volume of filling 67.5/13.55 = 4.97 cc.

Difference of volumes 3.07 cc.

Reduction of weighing to vacuum 3.07 x 1.200 mg. = 3.7 mg. True weight of the filling of mercury therefore 67.513 g. + 3.7 mg. = 67.517 g.

(N. B. The correction is positive as the volume of the weights is greater, whence greater buoyancy.)

Volume of filling therefore 67.517/13.5528 = 4.9824 cc. at 17.3°C.

Volume of 15°C. 4.9824 cc. − 2.3 ÷ 0.000025 ÷ 4.98 cc.
= 4.9824 cc. − 0.0003.
= 4.9821 cc.

RADIOGRAPHY AND CLINICAL PHOTOGRAPHY

This is a new publication published by the Eastman Kodak Co., of Rochester in the interest of better Radiography and Clinical Photography. It contains a number of interesting articles pertaining to this field.

Howard H. Bristol has been elected president of the Bristol Company, Waterbury, Conn. He succeeds his uncle, the late William H. Bristol, who was founder of the company.

NEW INSTRUMENTS

Recently Developed by Instrument Manufacturers

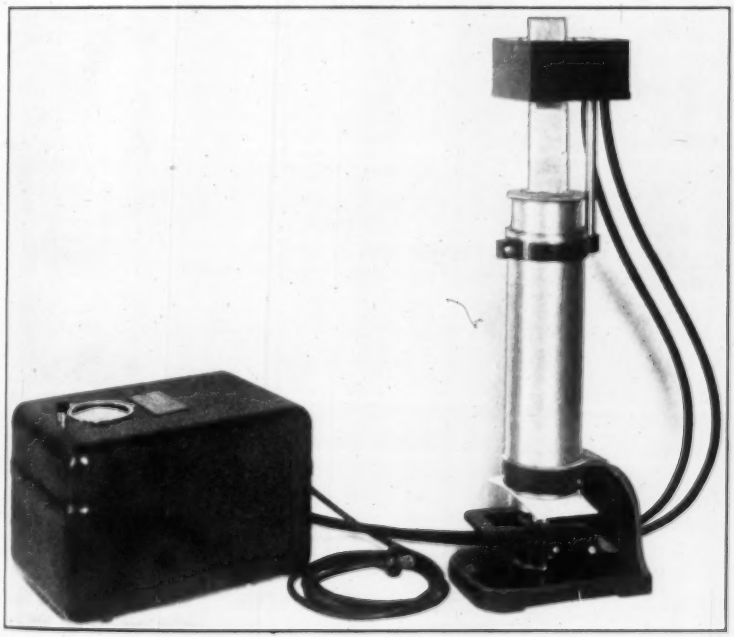
Write Information Section, Instruments Publishing Co., Pittsburgh, Pa., for additional Information.

New Model Densometer

(W. & L. E. Gurley)

THE Densometer test consists of forcing air at a low pressure through a standardized area of the paper sample. This is accomplished by clamping the paper between two orifice plates, having an opening of one square inch. Pressure is furnished by an inverted cylindrical cup which rides freely in an outside cylinder partly filled with oil. The air escapes through a central outlet tube to the orifice, and thence through the sample. The rate at which air passes through the sample is a measure of its porosity, expressed in seconds per 100 cc. Each 50 cc. is marked by rings on the outside of the inner cylinder, and the rate at which air escapes is obtained by timing the rings as they pass the upper edge of the outer cylinder, using a stop watch or other timing device.

The improved Densometer will give comparable results with the original model, but its design has been modified to test a wider range of materials, and to give a more uniform test, regardless of the skill of the operator. The clamping device is no longer a part of the inner cylinder, but is supported by the base of the instrument. Its weight is accordingly not limited, making possible the use of a better method of holding the sample. This has



resulted in a general improvement in the ease, speed, and accuracy of making the Densometer test.

The Densometer reading is the time required for 100 cc. of air to pass through the paper sample. It can be taken between any two lines, very dense samples being measured by reading between 50 cc. lines and multiplying by two. Porous samples may be measured by reading the time required to pass a greater quantity of air, as 200 cc. or 300 cc., and dividing by 2 or 3.

The Densometer is made entirely of metal, with nickel and black finish. The inner cylinder is adjusted to a weight tolerance, and carefully calibrated.

Height (extended)	20 in.
Base	5 in. x 8 in.
Weight	13 lbs.
Shipping Weight	17 lbs.

In the illustration is shown the Densometer with an automatic timing device, which is described below.

A device for automatically timing and recording the Densometer test brings the advantages of automatic timing for the testing of all kinds of materials. It is, however, most useful for dense samples, on which the Densometer test reading is several minutes or more, and also for eliminating the human error in timing the testing of very porous materials.

The attachment requires the attention of an operator only to start the test, and to turn on the current. The test is automatically recorded and stopped after the desired amount of air has passed through the sample, an obvious gain over the stop-watch method.

The automatic timing attachment consists essentially of a photo-electric cell which is exposed to light during the progress of the test. When the photo-electric cell is exposed, a relay is closed, and the current operates an electric Telechron clock. When the light is shut off, the circuit is broken and the clock stops.

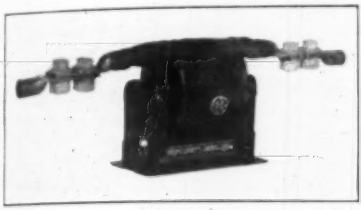
The attachment consists of two units, the photo-electric unit, and the timing unit, the former is supported above the Densometer. It contains the photo-electric cell and a 6-volt automobile headlight bulb, the two being separated by a sheet of metal having a narrow slot cut in it.

The timing unit, which is wired to the photo-electric unit, and also to the source of power, is contained in a separate case. It contains an amplifying tube which is actuated by the photo-electric cell, and, in turn, operates a relay. The relay starts and stops an electric Telechron clock. The low voltage for the lamps is furnished by a small transformer in the case.

Whenever the light is permitted to shine from the headlight bulb through the slit, and upon the photo-electric cell, the relay is closed, and the electric clock operates. The exposure of the photo-electric cell is governed by a vane attached to the inner cylinder. The vane passes the slot between the source of light and the photo-electric cell, and has an aperture cut in it to control the length of exposure. The length of this aperture corresponds exactly to the distance between rings on the cylinder, so that it is easily possible to run tests for 50 cc., 100 cc., or any quantity of air, up to 400 cc. Three vanes timing the Densometer test for 100, 200, or 300 cc., are included with each automatic timing attachment. Vanes for testing 50 cc. or 400 cc. are optional.

New Type Instrument Current Transformer

A new type of instrument current transformer embodying compensating features which practically eliminate ratio and phase angle errors and bearing the designation WF-1 has been announced by the General Electric Company.



The new transformer, built in ratings from 5 to 800 amperes and designed for 5000-volt operation is, for use in connecting watthour meters, instruments and relays, the combined burden of which does not exceed 50 volt-amperes. It has practically straight-line accuracy down to 5% load. The new transformer supersedes the WC-12 with which it is interchangeable as to dimensions. It is arranged for either flat-surface or pipe mounting, with a base which affords great accessibility. Two-bolt-hole terminals are employed on this new transformer.

Two-Stage Oxygen Regulator

(Oxweld Acetylene Company)

A CONSTANT line pressure free from any fluctuation is most desirable for good results in oxwelding. The Oxweld Type R-43 Oxygen Welding Regulator guarantees a freedom from fluctuation by means of a system of two-stage pressure reduction. This two-stage reduction is accomplished through two separate and independent sets of diaphragms, valves and springs. The full cylinder pressure of 2,000 lbs. enters the regulator through a stem-type valve and is controlled by the first stage diaphragm. In this stage the pressure is reduced to less than 250 lbs. / in. ^{2}. This pressure will be constant for any one regulator, but varies somewhat with different regulators. The pressure here is non-adjustable.

The oxygen then passes from this first reduction assembly to a second stem-type valve and diaphragm assembly where the pressure is reduced to the working pressure desired by the operator. This pressure is regulated by the operator by means of the adjusting screw, and any operating pressure may be obtained without fluctuation.

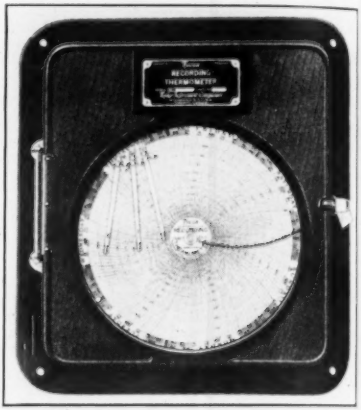
The external appearance is shown in the illustration. Instead of the usual handle-type pressure adjusting screw found on all other Oxweld regulators, there has been substituted a screw with a ribbed cap. This radical change in external design not only presents a neater and more

compact appearance but will also avoid the possibility of breakage as there are no projections on the handle to be bent accidentally. This new type adjusting screw is of smaller diameter than the body of the regulator itself so that it is easier to pack for transportation from one job to another.

Flush-Mounted Recording Thermometers and Pressure Gages

FOR those installations in which it is desirable to mount the instruments on a panel board, the Taylor Instrument Companies now offer Tycos Flush-Mounted Recording Thermometers and Recording Pressure Gages.

These instruments are available with one, two or three pens for recording one or more temperatures or pressures, being most valuable when three records are desired on one chart for easy comparison. The cases are of rigid aluminum casting, finished dull instrument-black.



Installation of these instruments is very easy as the case is rectangular in shape, measuring over-all 16¼" by 14½". Connections are made from the back and are out of the way but the tube system can be removed from the front.

The door of the instrument is mounted on spring hinges, insuring moisture and dust tight joints and the suspended pen arms are of stainless steel. The handy Tycos Chart-Ejection makes it easy to remove charts and a specially designed clock with three-point mounting insures further the faithful performance of this instrument."

A New Resistance Unit

(Hardwick, Hindle, Inc.)

THIS new resistance unit combines the ruggedness and high wattage of the vitreous enameled resistor with the convenience of being continually adjustable.

Along the surface of a refractory tube is space-wound a resistance wire having a low temperature coefficient of resistivity, with suitable terminals at both ends. This assembly is then enameled with a vitreous coating by a special process, which leaves a small arc of the upper surface of the turns exposed along a straight, narrow track. A suitable adjustment band and shoe are employed to furnish contact with the coil at any desired point.

A New Potentiometer Pyrometer

A VERY novel instrument for measuring and recording temperature has recently been developed by the Uehling Instrument Company, This instrument, which is known as the "Self-Contact" potentiometer pyrometer was primarily designed for measuring high temperatures as experienced in the iron, steel and ceramic industries. It lends itself equally well, however, to the measuring and recording of any temperatures where a high degree of accuracy is desired. Either a thermocouple or an electric resistance bulb may be used as the temperature element.

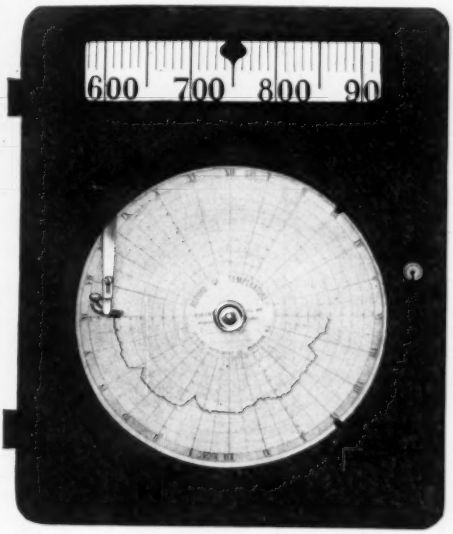


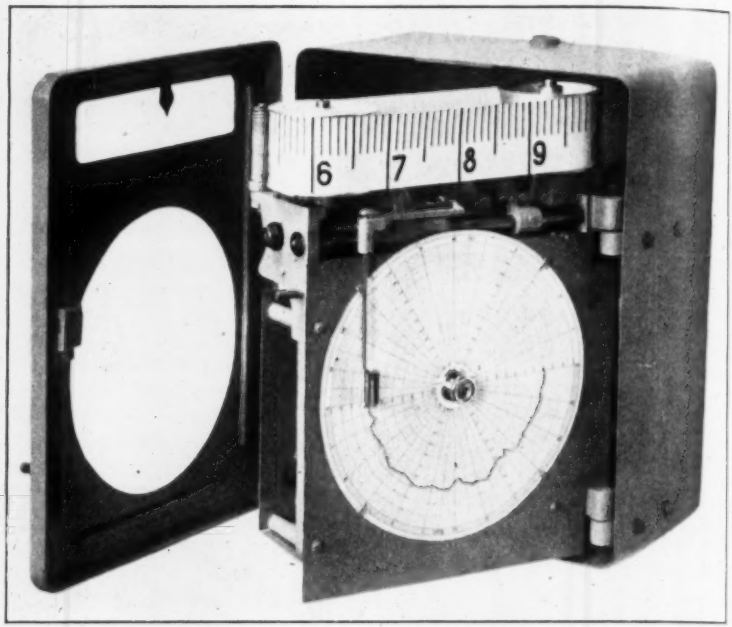
Fig. 1

The "Self-Contact" potentiometer pyrometer entirely eliminates the use of depressor bars, cam mechanism, and continuously operating motors. This is made possible by a patented method which assures definite and reliable contact between the needle of a galvanometer and stationary contact pieces, without in any way employing auxiliary mechanical devices which in one way or another conflict with the indicating needle.

Although the "Self-Contact" recorder retains all the advantages of the potentiometer, the novel contact method permits placing the galvano-meter apart, and at almost any distance from the recorder. This makes possible a very simple and rugged recorder construction that will withstand rough plant conditions and abuses, in a way that is impossible when the galvanometer forms part of the recording mechanism.

Fig. 1 illustrates the recorder which is actuated by a galvanometer that may be placed in any desired location, quite apart from the recorder. A single galvanometer will actuate as many as four recorders, each recorder in a different location, each measuring a different temperature, and if desired, each having an entirely different calibration.

The entire recording mechanism is fastened to a frame which is hinged to the case. Everything may therefore be opened up to permit accessibility to all parts of the apparatus. A small motor operates only as and when necessary to adjust the pen to the proper temperature reading on a clock driven chart. It is also in geared connection with two pulleys over which a translucent endless belt, about 2 ft. long, is placed. The belt is calibrated in temperature units and will move in direct proportion to the pen mechanism but at a greater speed. This permits a very open and legible scale



which moves in back of a pointer fastened to the door. The legibility of the figures, the exceptional length of the scale, and the fact that it is illuminated from the rear, make it very easily read under all conditions at a distance of 75 ft. or more. This is a very important feature which, due to the fact that the galvanometer does not form part of the recording mechanism, permits placing the recorder where it will most assist the operating staff.

INSTRUMENTS BOOK SHELF

The books reviewed in this section can be supplied by Instruments Book Shelf, Instruments Publishing Company, Pittsburgh, Pa.

TESTING OF REFRACTORY MATERIALS. *L. Litinsky.* Verlag Otto Spamer, Leipzig, 1930. Paper, 6 x 8½ inches, 127 pages.

While this is essentially a review and reprint of the articles appearing in "Feuerfest-Ofenbau," No. 1 to 4, of 1920, and treats essentially of the European practices for testing refractory materials, it contains a wealth of material on the testing of refractories in general.

Within its few pages such subjects as the "Determination of Particle Sizes," "Plasticity," "Viscosity," "Bonding Strength," "Porosity," "Fusion Point," "Thermo-Conductivity," and so on, are covered with a detail which permits one fairly familiar with the procedure of laboratory testing, to carry on a quite thorough research program and, in fact, control his entire output by means of these tests.

The non-European testing engineer will find it rather difficult to duplicate all of the apparatus described, as there is no American counterpart for much of the apparatus shown. After reading the book, one is impressed by the need for suitable testing apparatus in America.

The book is well-written and covers its subjects quite thoroughly. A rather novel feature is brought in by the author in that he gives sources of supply for practically all of his apparatus used.

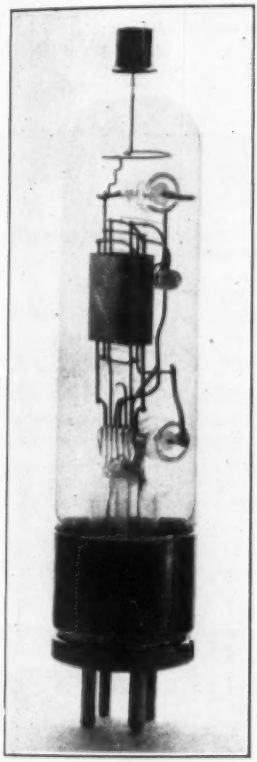
This will counteract his one omission—that of giving detailed specifications for the various pieces of equipment he recommends using.

All in all, the book is quite thorough and is recommended most heartily.—Arthur Schroder.

Vacuum Tube for the Measurement of Small Currents

A HUNDRETH of a millionth of a billionth of an ampere can be measured by means of a new type of vacuum tube developed by the General Electric Company. The electron flow is such that a current expressed as 10^{-17} ampere, compares with the electron flow through the usual 50-watt incandescent lamp as do two drops of water with the enormous volume of water spilled over Niagara Falls in a year. Something like three quintillion electrons-second flow through the ordinary 50-watt incandescent lamp; the new vacuum tube is able to mea ure accurately a flow of about 63 electrons/second.

The new four-element tube is so sensitive to infinitesimal flow of current that astronomers can use it with photoelectric tubes in determining the amount of heat radiated by stars countless miles away—bodies so far away in space that, in spite of their enormous size, they remain simply as points of light, however powerful the telescope through which they are viewed. The current is measured in fractions of quadrillionths of an ampere—the stellar distances in multiples of quadrillions of miles.



In the measurement of small currents the new tube will, to a great extent, replace electrometers which are now used. The tube has the advantages of greater sensitivity and much greater ease of mounting.

One of the major applications will be in the laboratory measurement of currents in ionization chambers which are used to indicate the intensities of X-ray and ultra-violet light beams. It is usually desirable to have this ionization chamber movable. The ordinary electrometer, however, must be rigidly fixed in position. To connect the ionization chamber and the electrometer presents something of a problem since the insulation resistance of the connecting wire must be extremely high and the capacity very low. The low grid current tube may be mounted directly on the ionization chamber and flexible leads run from it to the indicating galvanometer, greatly simplifying the measurement work.

Another important application of the tube will be in the photoelectric measurement of stellar intensities. At the Washburn Observatory in Madison, Wisc., work is now being done on apparatus for the giant reflecting telescope for California, the 200-inch fused quartz mirror for which is now being constructed at the Thomson Research Laboratory of the General Electric Company at Lynn, Mass. Professor Joel Stebbins, director of the Washburn Observatory, is using two of the low grid current tubes in connection with a quartz photoelectric tube to indicate the position, intensity and spectrum of even very faint stars. It is possible, according to Professor Stebbins, to make nearly all astronomical observations photoelectrically rather than visually or photoelectrically as has been done in the past, with decided advantages in rapidity and sensitivity. The low grid current tube improves the photoelectric method considerably since the tube replaces a special type of electrometer designed to be mounted on the end of the telescope and moved about with it. This special requirement results in an electrometer of low sensitivity. Using the low grid current tube the galvanometer may be mounted permanently on a bench and the tube placed with a photoelectric tube at the end of the telescope.

CONSTRUCTION OF THE TUBE

The tube is one in which the grid current is reduced to a very low value. The grid of a tube is usually thought of as taking no current, but in the ordinary types of tubes there is a flow of up to a millionth of an ampere to the grid. To determine what means could be adopted to decrease this current flow, an analysis of the sources was made by the engineers of

the vacuum tube engineering department of the General Electric Company. They found seven factors contributing to this grid current flow:

(1) Electrons from the filament.
(2) Positive ions formed by collision between the electrons constituting the plate current and the gas molecules in the space.
(3) Electrons emitted by the grid because of its temperature.
(4) Leakage.
(5) Positive ions emitted by the filament.
(6) Electrons emitted from the grid under the influence of light from the filament (Photoelectric effect).
(7) Electrons emitted from the grid under the influence of the soft x-rays given off by the plate because of its bombardment by the plate current.

Each of these seven factors was investigated in turn, and the means for reducing each was found and applied. The first source, electrons from the filament, was eliminated by operating the grid with a negative bias exceeding three volts.

Partial success in eliminating the current resulting from positive ions formed from the gas in the tube was attained by very thoroughly exhausting the tube. Further reduction was attained by operating the tube with all voltages below the ionization potentials of any gases present.

By the use of low-powered filaments, the thermal electron emission from the grid was eliminated.

Leakage, a source of considerable currents, was reduced greatly by mounting the grid on quartz beads, shielded by a skirt of glass to prevent surface contamination.

The positive ions reaching the control grid from the heated filament were eliminated by placing a fourth element, a space-charge grid operated at positive potential, between the filament and the control grid.

The photoelectric emission of electrons was reduced by using a thoriated tungsten filament operated at low temperature.

An X-ray tube has an anode bombarded by electrons at high voltage; a vacuum tube has all the essential features of an X-ray tube except that the voltage is low and hence the X-rays are very soft. It was found that the currents resulting from the soft X-rays varied greatly with anode voltage and surface contamination of the grid, and that they became negligible when the anode potential was less than six volts.

Having analyzed these 7 sources of grid current and found means for reducing each of them the low grid current tube was produced with the following characteristics:

Plate voltage	6.0 volts
Space-charge grid voltage	−4.0 volts
Control grid voltage	4.0 volts
Filament voltage	2.5 volts
Filament current	110 milliamperes
Plate current	40 microamperes
Mutual conductance	25 microamperes/volt
Plate resistance	40,000 ohms
Amplification factor	1.0

The currents produced may be amplified and made to activate relays or control equipment which is impossible with the conventional electroscope or electrometer. Not only is the tube sensitive to such a minute current as 10^{-17} ampere, but it has a current amplification factor of a billionfold, or a hundred millionfold when taking the circuit into consideration. The usual radio receiving tube has a thousandfold amplification as a tube, or a hundredfold in the circuit.

The current handled by the tube is so small that in flowing through a resistance of a million megohms (1,000,000,000,000 ohms), practically a perfect insulator in common thought, it produces a drop of only one millivolt (.001 volt).

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Krupp High Precision Mikrotast Pillar Stand

(Coats Machine Tool Co. Inc.)

FOR checking close limits of .0001" and .00005", combined with easy reading and high accuracy, the Mikrotast Gauge will be found very suitable. The fan-shape indicator (as illustrated) is graduated either in 50 x .0001" or 40 x .00005" graduations, the scale range being therefore .005" and .002" respectively. Each division on the scale is slightly less than $\frac{1}{16}$" wide, insuring good visibility. Red limit markers, adjustable from without the case, are located above the scale and can be instantly moved to any desired position and locked in place.

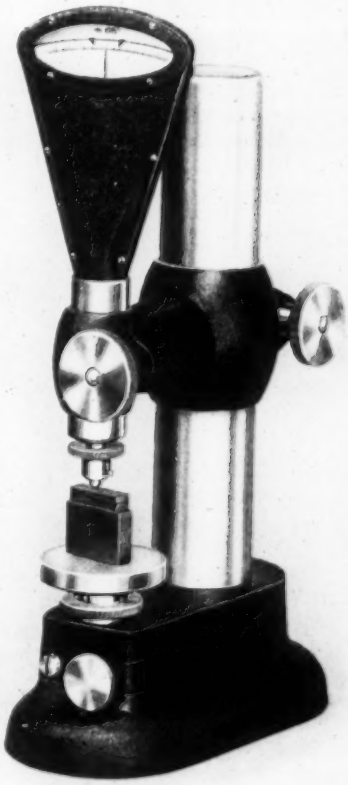

Fig. 2

Accuracy is of major importance in an indicator reading as close as .00005" and with this in mind, the amplification unit in the mikrotast head has been built up on the knife-edge principle. All knife-edges and their sockets are made of special non-wearing metal. It is therefore claimed that wear has been practically eliminated; also the lever arm length of .008" insures perfect marginal accuracy, in spite of the fact that the scale is 2$\frac{3}{8}$" long. The contact spindle is made of special hard steel and is faced with Krupp "Widia" metal, the wearing property of which is equal to a diamond. A thumb-nut just above the contact point is provided to raise same for testing thin materials or delicate parts which must not be scratched. To prevent a sudden overload of the knife-edge system, a flange is provided on the lower transmission rod.

Coarse adjustment for height is made through the arm holding the fan-shaped Mikrotast Indicator which is clamped to and can be swung round the 2″ pillar. Fine adjustment is made by a micrometer screw which raises the table with the work on it. The table is then locked in position by means of the knurled screw located in front of the base. The maximum distance between the contact point and the table is 7″, capacity for rounds is 5″. The 2 3/8″ diameter ground and lapped table is interchangeable with various sized tables or Krupp Mikrotast Saddle Gauges for cylindrical work.

This Mikrotast Pillar Stand has also been adapted for testing very fine wire, as, for instance, tungsten and magnet wire. In this case, a special anvil electrically insulated takes the place of the table, a small wooden box containing a 3—4.5 volt dry cell is located on top of the pillar and an adjustable stop ring is slipped round the pillar under the arm holding the Mikrotast Indicator.

The insulated anvil is hooked up with the dry cell by a wire and the contact point of the indicator is also connected with the cell. In order to complete the circuit therefore, the contact point must touch the anvil. By raising the contact point or gaging end from the anvil, a gap can be set within the range of the indicator used. The wire to be gaged is drawn as tight as possible across the surface of the insulated anvil and pushed through the gap. If the wire is too heavy, the gap will be closed, i. e., the circuit completed and a red bulb, directly above the Mikrotast scale, will light up. This is a good way of checking up on fine wire dies and, by this method, contact pressure is entirely eliminated so that fine wires up to .002″ diameter will not be deformed. The accuracy of the electrical contact between gaging contact point and anvil is approximately .000004″ (four millionths of an inch) i. e., there is a hardly perceptible motion of the indicating hand when the bulb lights up.

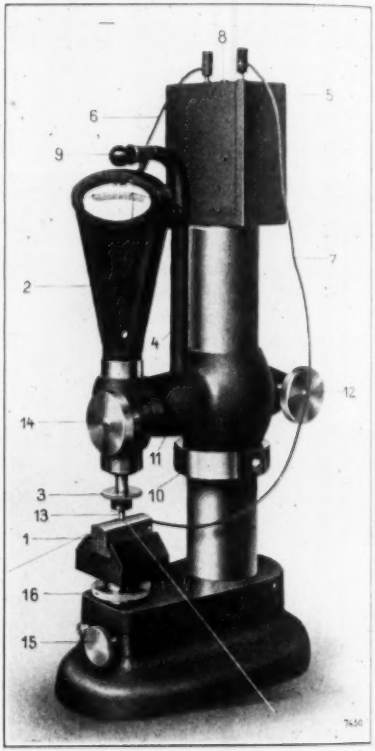

Fig 2

The Roller Smith Co. announces the appointment of J. K. Webb, 601 Allen Building, Dallas, Texas, as its District Sales Agent for the State of Texas.

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THE FOG HORN. The August 1930 issue illustrates the application of humidifiers to textile mills. Parks-Cramer Company, Fitchburg, Mass.

TIME RECORDERS. Bulletin No. 8301 is entitled "Time Recorder Speeds Up Production in Electric Welding Department." This bulletin illustrates the application of recorders to time study. Esterline-Angus Co., Indianapolis, Ind.

ELECTRIC MOTOR GAS VALVES. A leaflet describing the electric motor gas valve with automatic shut-off. It covers the operation of the various models of this valve. Minneapolis-Honeywell Regulator Co., Minneapolis, Minn.

POLAROGRAPH. This leaflet illustrates an automatic recorder for current-voltage curves. The leaflet is printed in English. Dr. V. Nejedly, Prague 19, Husova Tr. 76., Czechoslovakia.

MICROSCOPE OBJECTIVE. The 20 page booklet is entitled "The Creation of a Microscope Objective." This booklet is divided into three sections: 1. Calculation, 2. Construction, 3. Testing. Emil Busch Optical Co., Ltd. 37 Hatton Garden, London, E. C. 1.

AIR PHOTOGRAPHY. Leaflet illustrates photographs both vertical and oblique taken with the Junkers Camera. This leaflet is printed in German. Junkers-Flugzeugwerk A. G. Dessau, Germany.

NEW TOOLS. Supplement to Catalogues Nos. 31 and 139. Illustrates a number of new Brown & Sharpe measuring tools, as Micrometer Calipers, Telescoping Gages, Depth Gages, etc. Brown & Sharpe Manufacturing Company, Providence, R. I.

GAS SERVICE JOURNAL. The August issue of this publication contains the following articles: "Operation of Meters in Natural Gasoline Plants; Storing Gas in Earth's Natural Reservoirs; Economic Operation of Small Gas Wells; Distributing Butane-Air Gas at North Manchester, Ind. Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

FLOW GAGE. Leaflet describes the Collins Flow Gage—A Combination of the Collins Impact Tube and Water-Air Manometer. Arthur L. Collins, 7 Front St., San Francisco, California.

AUTOMATIC TEMPERATURE CONTROL GAGES. 8 page booklet illustrates the application of Trent Temperature Control Gages for temperature up to 1000°F. Harold E. Trent Company, 439 N. 12th St., Philadelphia, Pa.

AUTOMATIC CONTROLS FOR OIL BURNERS, UNIT HEATERS AND INDUSTRIAL APPLICATIONS. Catalog H-6 contains the latest information on these various control devices. 112 pages. The Mercoid Corporation, 4201 Belmont Ave., Chicago, Ill.

MULTIPLIER TABLES. Loose-leaf, Lefax size booklet containing table of pressure multipliers used to correct volumes at a given base pressure. Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

CHEMICAL PRICE LIST. Leaflet of prices dated September 1930. J. T. Baker Chemical Co., Phillipsburg, New Jersey.

CONTROL EQUIPMENT FOR STEEL MILL AUXILIARIES. Leaflet GEA-1290 covers the CR 4261 Type MT Control Equipment for Direct-current, Series-wound or Compound-wound Motors. Leaflet GEA 388A covers MT Control Equipment for Direct Current, Series-Wound Crane-Bridge and Trolley Motors. Leaflet GEA-530B covers Type MT Control Equipments for D-C, Series-wound Crane Hoist Motors. General Electric Co., Schenectady, N. Y.

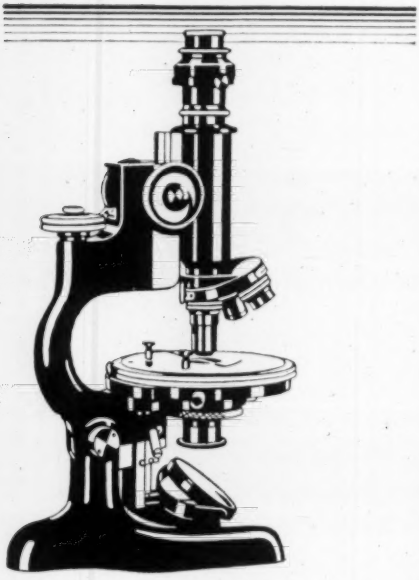
WATER WORKS JOURNAL. The August issue of this periodical contains the following: A Story of Fullerton, California Water Works System; Some Points of Conflict Between Municipalities and Water Companies. Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

THERMOSTAT. Leaflet GEA-1265A describes the type CR 2962-A1 Thermostate for use with Industrial Heating Units. General Electric Co., Schenectady, N. Y.

SWITCHES. Leaflet GEA-1096A gives engineering data and illustrations of Type LG-11SB Indoor Disconnecting Switches. Leaflet GEA-1283 covers CR 3012 Cam-Type Master Switches for Use on Control Circuits Only. Leaflet GEA-1284 covers CR-9441 Geared-Type Limit Switches Cam-operated. Leaflet GEA-1285 covers CR-9441-LS-438 Track Type Limit Switches for Control Circuits. General Electric Co., Schenectady, N. Y.

RESISTORS. Leaflet GEA-1295 describes and illustrates Type CR-9132 Edgewise-Wound Resistors for Alternating-and Direct-Current Service. General Electric Co., Schenectady, New York.

GENERAL RADIO EXPERIMENTER. The July 1930 issue of this publication contains an article entitled, "The Continuous Recording of Pulse Rates. The instrument used for this is the cardiotachometer. General Radio Co., Cambridge A, Mass.



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SELSYNS FOR REMOTE SIGNALING, CONTROL, AND INDICATION. Catalogue G.E.A.-722 B describes the application of Selsyn Motors. Many of these applications are in instrument fields. General Electric Co., Schenectady, N. Y.

HERSCHEL OILINESS MACHINE. Bulletin No. 112 discusses the definition of oiliness and describes the Herschel Oiliness Machine for testing the friction reducing properties of lubricants and bearing metals. American Instrument Co., 774 Girard St. N. W. Washington, D. C.

ABRASION TESTER. A leaflet illustrating and describing the Herzog and Geiger laboratory wear tester. H. Z. Schniewind, 72 Duane St., New York, N. Y.

TEST JACK FOR TYPE OF DETACHABLE WATTHOUR METERS. Leaflet I.-268 covers the distinctive features of the test jack. Permanent test facilities for each meter are eliminated, actual test connections are made with the tools, service is not disturbed in any way, and all live parts are adequately insulated. Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.

UNIT AIR CONDITIONER. Form 1 illustrates and describes the ParkSpray Unit Air Conditioner (type NCH) which is a compact, efficient, entirely self-contained device for completely conditioning the air. Parks-Cramer Company, Fitchburg, Mass.

CHEMICAL PRICE LIST. J. T. Baker Chemical Co., Phillipsburg, N. J. issued a new catalogue of C. P. Chemicals and Acids and other laboratory and technical chemicals, July 1, 1930.

CHEMICAL PLANTS NEED RELIABLE PYROMETERS is the title of a direct mail piece sent out by Leads & Northrup Co., 4901 Stenton Ave., Philadelphia, Pa.

MIKROTAST INTERNAL GAGES. A four page bulletin covers the following: Fixed Internal Gages, "Go" and "No Go" Plug Gages. Coats Machine Tool Co. Inc., 110 W. 40th St., New York, N. Y.

INDUSTRIAL REGULATORS. A loose leaf folder contains bulletins on the following items: Industrial Motor Valves; Industrial Motors; Motor Radiator Valves; Electric Motor Oil Valves; Electric Motor Valves; Solenoid Operated Magnet Valves; Temperature Controllers; Pressure Controllers; Combustion Safety Controllers; and Industrial Control Equipment. Minneapolis-Honeywell Regulator Co., Minneapolis Minn.

UNIT HEATER AND SECTIONAL CONTROL SYSTEMS. A 24-page bulletin discusses the Minneapolis-Honeywell Control designed to meet the requirements of all types of installations. Minneapolis-Honeywell Regulator Co., Minneapolis, Minn.

THE SPERRYSCOPE. Vol. 6, No. 1 of this publication contains an article entitled "Dr. Elmer Ambrose Sperry," in memory of the death of this instrument designer and builder. Other articles: Doing a Transcontinental in a Wing Covered Wagon 1930; The Country Mansion Goes to Sea and S. S. Santa Clara Completes Record Voyage. Sperry Gyroscope Company, Inc., Manhattan Bridge Plaza, Brooklyn, N. Y.

TIME AND REMOTE CONTROL SWITCHES. Catalogue No. 4, Sec. 1 gives a number of applications of such switches. The various parts of the switches are described and the various models illustrated. The States Company, Hartford, Conn. Sec. 2 of the same catalogue covers oil break switches.

STATAMATIC TEMPERATURE REGULATOR. A.I.A. file No. 30-F-2 describes a temperature regulator for holding different day and night temperatures. The States Company, Hartford, Conn.

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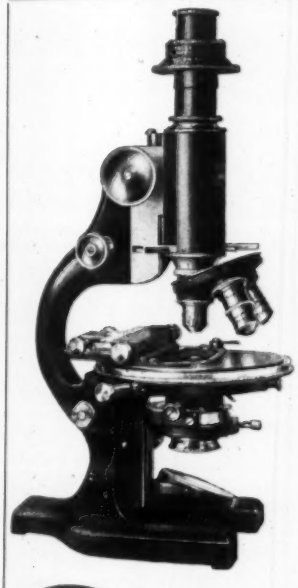

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MAGNETISM

The Application of the Thermo-Magnetic Analysis on the Study of some Iron Ores and their Oxydes (Anwendung der thermo-magnetischen Analyse auf das Stadium einiger Eisenmineralien und deren Oxyde) J. Hugget & G. Chaudron, Korrosion & Metallschutz, April 1930, pages 79-82.

The new instrument for thermo-magnetic analysis developed by Chaudron-Forestier is applied for the study of some iron minerals and oxides—E. F.

An Experimental Method for the Determination of the Ballistic Demagnetization Factor, D. Foster, London, Edinburgh & Dublin Philosophical Magazine & Journal of Science, Sept. 1929, pages 304-313.

By means of a double search coil of novel design the magnetization and the field intensity are determined from ballistic galvanometer deflections. While the discussion refers mainly to circular cylinders, the scheme is adaptable to specimens of other shapes. It is particularly designed to obtain accurate measurements of field intensities in cylinders of small diameter. Curves are given which illustrate the variation of the demagnetization factor with the magnetization, as well as the dependence of this relation on the material and on the dimensional ratio.—E. F.

MICROSCOPY

Dark Field Microscopy of Thinnest Films On Liquid Surfaces (Dunkelfeldmikroskopie dunnster Filme auf Flussigkeitsoberflachen) H. Zocher & F. Stiebel, Zeitschrift fur physikalische Chemie, May 1930, pages 401-435.

Mono-molecular layers of organic substances on water were microscopically investigated under various conditions in the Kaiser Wilhelm Institut fur physikalische Chemie und Elektrochemie by dark field illumination. Numerous pressure surface curves were determined. —E. F.

Don't Be Afraid of the Microscope! E. R. Schwarz. Textile World, May 24, 1930, pages 34-37.

The author emphasizes the necessity for recording the result of microscopic investigations. He discusses the advantages and disadvantages of written records, drawings and photographs.—G. N.

LENGTH, AREA AND VOLUME

Telescoping Gages. Textile World, May 3, 1930, pages 108-109.

New telescoping gages are manufactured by Brown & Sharpe Mfg. Co., Providence, R. I., which are used to determine internal measurements formerly difficult to obtain.—G. N.

Roll Indicating Caliper. India Rubber World, April 1, 1930, page 77-78.

The instrument described was developed by the Farrel-Birmingham Co., Ansonia, Conn., for measuring large calender rolls and for determining their accuracy and the amount of crown or concavity. The instruments are built in five sizes for rolls 20 to 50 inches, 16 to 42 inches, 11 to 32 inches, 8 to 24 inches and 4 to 17 inches in diameter.—G. N.

"Bulkometer" simplifies Concrete Proportioning. J. V. Schaefer. (Cement Gun Construction Co., Chicago). Engineering and Contracting, May 1930, page 209.

The "Bulkometer," as described by the author, permits the determination with an accuracy within practical limits the effect of moisture in producing bulking of sand.—G. N.

Ammonia-Treated Gage Steel. A. J. Wormwood, Supervisor of Gages, Independent Pneumatic Tool Company. American Machinist, Vol. 72, Mar. 13, 1930, page 452.

A plug gage made from machinery steel and carburized with previously used material gaged an average of 90 holes per gage. Gages from the same steel but carburized with new material averaged 320 holes per gage. Gages from steel conforming to S. A. E. 5195 specifications averaged 340 holes per gage. Gages from oil hardened steel quenched at 1500°F. and drawn to 300°F averaged 640 holes per gage. Gages from ammonia treated steel, known as nitralloy show best results gaging an average of 1,044 holes per gage before showing appreciable wear.—R. H. P.

Gages for Measuring of Interior Threading (Zusammensetzbares Stichmass mit Feineinstellung zum Messen vol Innengewinden). Zeitschrift fuer Feinmechanik und Praezision, May 31, 1930, pages 1-2.

Description of a gage with exchangeable parts made by Carl Zeiss, Jena.—Ha.

SURVEYING

Set-Up of Axis of Rotation in Polygon-Line-Measurements in Open Air and Under Earth (Drehzapfenaufstellung fuer Polygonzugvermessungen ueber und unter Tage) P. Wilski, Zeitschrift fuer Instrumentenkunde, Nov. 1929, pages 550-552.

In contrast with measurements of lengths, the angle measurement still requires improvements, one of which this paper deals with.—E. F.

Cinematographic Theodolyte of the Askania-Werke Aktiengesellschaft (Kino Theodolit der Askania-Werke Aktiengesellschaft) H. Fuss, Zeitschrift fuer Instrumentenkunde, Nov. 1929, pages 529-540.

A recording theodolyte, destined for the determination of the course of a body free moving through space, is reported on which has recently brought on the market by the Askania Works. The mode of operation of the delicate instrument is described in details and illustrated in a large number of figures.—E. F.

Accuracy of Results in Optical Measurement of Distances According to the Prescriptions of the Wuertembergische Amtliche Technische Anweisungen fuer Katastervermessung (Genauigkeitsergebnisse eines Vergleichs optischer Distanzmessungen mit Messungen entsprechend der Wuertembergischen Amtlichen Technischen Anweisungen fuer Katastervermessung) W. Schneider, Zeitschieft fur Instrumentenkunde, Nov. 1929, pages 541-550.

This paper from the Technische Hochschule Stuttgart critically compares the standard methods for the determination of distances as used in the State of Wuertemberg.—E. F.

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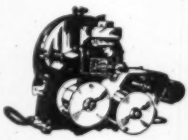

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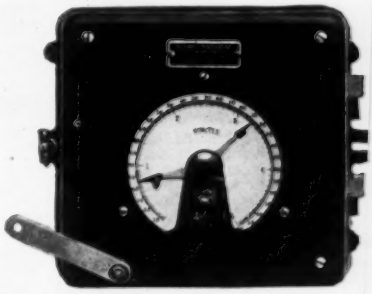

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GASES, AIR AND STEAM

On Wind Measurements and Wind Measuring Instruments (Etwas uber Windmessen und Windmessgerate). Zeitschrift fuer Mechanik und Praezision, June 29, 1930, pages 11-14.
Description of a few instruments of the Askania-Works.—Ha.

The Development of the Bellow-Meter (Aus der Entwicklung des Einbalgmessers). W. Marx. Messtechnik, July 1930, pages 177-181.
The fundamental differences between valve-gas meter and single bellow-gasmeter are described. To obtain correct measurements in the latter the leather diaphragm must have a suitable shape. The proper dimensioning of all parts and use of high-grade materials have lead to a high state of perfection of this meter which, besides, is little sensitive to dirt and variations of pressure.—Ha.

Calibration and Lag of a Friez Type Cup Anemometer. R. Pinkerton, Technical Note 341, National Advisory Committee for Aeronautics, 8 pages.
Tests on a Friez type cup anemometer have been made in the Variable Density Wind Tunnel of the Langley Memorial Aeronautical Laboratory to calibrate the instrument and to determine its suitability for velocity measurements of wind gusts. The instrument was calibrated against a Pitot static tube placed directly above the anemometer at air densities corresponding to sea level and to an altitude of approximately 6000 feet. Air speed acceleration tests were made to determine the lag in the instrument reading. The calibration results indicate that there should be an altitude correction. It is concluded that the cup anemometer is too sluggish for velocity measurements of wind gusts.

ELECTRICITY

Electrical Measuring Instruments in Rooms with Danger from Explosions (Elektrische Messinstrumente in explosions gefaehrlichen Raeumen). Ad. Gaier. Elektrizitaet im Bergbau, May 22, 1930, pages 89-90.
General principles for the development of such instruments and necessary means of protection according to the German VDE-rules.—Ha.

The Electrical Test Floor and the Electrical Machine as Braking-Dynamometer (Das elektrische Pruefeld und die elektrische Maschine als Bremsdynamd). F.-A. Foerster, Elektrizitaet im Bergbau, May 22, 1930, pages 84-89.
General discussion of testing of electrical machines and determination of efficiencies by dynamometer method.—Ha.

Location of Failures in High-Tension Transmission Lines By An Alternating Current, Method (Fehlerortbestimmung an Hochspanuungs freileitungen nach einer Wechselstrommethode). Hans Poleck, Wissenschaftliche Veroeffentlichungen aus dem Siemens Konzern, 1930, No. 1, Vol. 9, pages 298-328.
The author develops the fundamental theory for the determination of defects in high-tension transmission lines for the possible kinds of defects, namely short-circuits and breaks with and without ground. A graphic and a numerical solution is described and all defects reduced to one measurement by a bridge-method which suffices for theoretical and practical purposes and which also makes possible a measurement when an influence by induction from the high-tension lines is present.—Ha.

The Measuring of Earth Currents (Die Messung von Erdstromen). Ad. Gaier, Elektrizitat im Bergbau, July 20, 1930, pages 141-143.
The principles of measuring earth-currents are briefly discussed and an earth-ammeter is described which permits simply measuring the leakage currents from pipes, rails, etc., in the ground.—Ha.

The Calculation of Reactances Without Iron (Die Berechnung eisenloser Drosselspulen). D. Faye-Hansen. Elektrotechnische Zeitschrift, March 20, 1930, pages 427-429.
A few empirical formulas for the self-induction of circular and rectangular section are developed which are correct within wide limits. For coils of definite length, an additional member in the enumerator takes the magnetic resistance outside the length of the coil into account. Similarly formulas for the self-induction of parallel rectangular rails and bars are developed.—Ha.

Measurements of Loss Angles and Efficiencies by Means of the Thermal Wattmeter (Verlustwinkel-und Wirkungsgradmessungen mittelst der thermischen Wattmeters). A. Herzog. Elektrotechnische Zeitschrift, March 20, 1930, pages 421-423.
A modified form of a hot-wire wattmeter is described and a method developed for measuring and recording in daily routine operation dielectric losses especially of cables where the power factor is very low. It is also shown how the same method can be applied for measuring certain efficiencies by determining the difference of two efficiencies. This method will be correct to about 10%.—Ha.

The Cross-Coil Ohmmeter in Remote Measurements (Das Kreuzspul-Ohmmeter in der Fernmesstechnik). Jul. Moeller. Messtechnik, June 1930, pages 149-152.
The principle of this instrument consists of two coils arranged in an acute angle between cylindrically shaped poles and an elliptically shaped iron core. There is no directing force when no current passes the coils. If current passes, the coils will assume a position that the magnetic fluxes in the coils are proportional to the resistances of the respective coil circuits. The instrument can be used for remote measuring of temperatures, and also of other quantities of electrical, thermal, or mechanical nature.—Ha.

An Amplifier for Measuring Small Currents. R. D. Bennett. Review of Scientific Instruments, Aug. 1930, pages 466-470.
An amplifier is described which uses a four electrode tube of the ordinary type, and gives maximum current sensitivities of the order of 10^{-18} amperes. A novel feature consists in using as grid leak the positive ion emission of the filament.

A Theoretical and Experimental Study of the Resonance Radiometer. J. D. Hardy. Review of Scientific Instruments, Aug. 1930, pages 429-448.
A galvanometer system for the measurement of very small voltages, of the order of 10^{-11} volts, is described and its application to the measurement of feeble radiations with a thermocouple discussed. It has been found that energies of the order of 1/200 of that previously detected by other devices could be measured with the Resonance Radiometer. The effect of the Brownian Movement on the system has been calculated and has been found to be about 1/200 that of the effect on the ordinary galvanometer. An experiment is described for the measurement of the speed of action of thermocouples, and results on the splashed filament type are recorded.

A Cathode Ray Hysteresigraph. R. A. Chegwidden. Bell Laboratories Record, June 1930, pages 462-464.
The operation of the Johnson hysteresigraph is briefly described.

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The Testing of Condenser Paper. F. L. Roman. Preprint 101, American Society for Testing Materials, 13 pages.

This paper discusses the relationship between several characteristics of condenser paper made from linen stock and the dielectric strength (breakdown voltage) of the condensers wound with this paper. Condenser papers 0.0004 and 0.0005 in. in thickness, from foreign as well as domestic sources, are included in this study. The conclusion is reached that variations in the density of the condenser paper have no noticeable effect on the dielectric strength of the corresponding condensers. It is shown that, when in small numbers, conducting paths through the paper have no important effect on the dielectric strength of condensers wound with two sheets of the paper between tinfoils but that the percentage of "shorted" condensers or of condensers failing at very low voltages may be expected to increase approximately as the square of the number of conducting paths per unit area of the paper. Variations in the porosity of the paper are shown to have marked influence on the dielectric strength of the corresponding condensers and porosity requirements for papers used in low-voltage condensers and for papers used in high-voltage condensers are suggested.

A High Resistance Leak for Electrometer Use. A. K. Brewer. Review of Scientific Instruments, June 1930, pages 325-328.

Currents of the order of 10^{-13} amps can readily be measured by measuring the potential drop across a high resistance leak with a quadrant electrometer of small capacity. This article describes a method for simply and easily making the high resistance leak.

The Dielectric Strength of Cable Paper. (Die Durchschlagfestigkeit von Kabelpapier.) Andreas Gyemant. Wissenschaftliche Veröffentlichungen aus dem Siemens-Konzern. Vol. VIII part 3, 1930, pages 191-202.

Tests made on 2 different kinds of cable insulating paper show that the dielectric strength is independent of the humidity if the relative humidity is less than 75%. In spite of a large difference in air tightness, ratio 1:16, of the two grades, the difference in dielectric strength is small, 1.7:1. The dielectric strength for d. c. is 10 to 15% higher than for a. c. Under treatment with ultraviolet light the dielectric strength is not reduced. When the same test piece is punctured several times the second value is lower than the first but the following values are about the same. The theoretical conclusions are that the insulating properties of paper are due to the air in the pores. They are higher than for air alone because the pore walls of the paper absorb energy, requiring a higher voltage for puncture. Several references are given.—C. E. M.

A New Rate-Meter of the Aron Works (Ein neuer Tarifapparat der Aronwerke). Elektrotechnische Zeitschrift, Feb. 13, 1930, page 250.

A combination of switch-clock and meter permits the installation to be connected only during times of preferred rates for energy consumption. The apparatus is described in detail.

A High-Tension Voltmeter. (Ein Hochspannungsvoltmeter). A. Nikuradse. Elektrotechnische Zeitschrift, Feb. 13, 1930, page 250.

The instrument consists of 2 horizontally arranged discs, the upper one has a circular disc in the centre cut out and suspended on a spring. Variable voltage moves this central part; the calibration curve in logarithmic representation is a straight line which makes adjustment and calibration easy. Ha.

The New Temperature Compensated Induction Meter of Siemens-Schuckertwerke (Der neue temperaturunabhaengige Induktionszaehler der Siemens-Schuckertwerke, eine einfache Loesung auf dem Gebiete des Temperaturausgleichs). A. Callsen. Elektrotechnische Zeitschrift, Feb. 27, 1930, pages 307-311.

After discussing the influences of temerature on the indication of a meter and the means adopted by several manufacturers to counteract them the author describes the new method of SSW in their small meter for house installations. The heat-compensation is effected by the arrangement of a heat-alloy which keeps magnetic flux as well as phase-angle constant over a wide range of temperature. Ha.

Automatic Voltage Regulator (Selbstaetiger Spannungsregler). P. Toulon. Elektrotechnische Zeitschrift, Feb. 6, 1930, pages 213-214.

Series connection of an ohmic resistance and neontube in such manner that the terminal voltage can be kept almost constant; for 10% voltage variation the regulation is ±0.2. Ha.

Oscillographs. Zeitschrift Verein deutscher Ingenieure, Feb. 22, 1930, pages 239-242.

This paper is a review of construction and action of all types of oscillographs, their particular properties, sensitiveness, and ranges. Electro-dynamic electro-static loop oscillographs possess a certain inertia while cathode-ray oscillographs are practically without inertia. For oscillations up to 6000 Herz the instruments of the former type can be used, for higher frequencies cathode-ray instruments must be used. Today, frequencies up to 10^7 Hz can be recorded oscillographically. H

Measurements of Loss-Angles and Efficiencies by Means of the Thermal Wattmeter (Verlustwinkel-und Wirkungsgradmessungen mittelst des thermischen Wattmeters) A. Herczeg. Elektrotechnische Zeitschrift, Mar. 20, 1930, pages 421-423.

A modified form of hot-wire wattmeter is described and a method developed for measuring and recording in daily routine operation dielectric losses especially of cables where the power factor is very low. It is also shown how the same method can be applied for measuring certain efficiencies by determining the difference of 2 efficiencies. This method is accurate to about 10%. Ha.

POWER, WORK AND OUTPUT

The Engine Indicator as a Guide to Performance. H. A. Gehres. Cooper-Bessemer Monthly, June 1930, pages 3-5, 19; July 1930, pages 3-5, 19.

The article discusses the indicator card in compressor work.

Remote Locomotive Engine Indicator (Lokomotiv-Indikator mit elektrischer Fernbetaetigung). Zeitschrift fuer Feinmechanik und Praezision, Nov. 30, 1929, pages 5-7.

The latest model Lehmann & Michel locomotive engine indicator is described.

TEMPERATURE AND MOISTURE

A Self-Compensating Temperature Indicator. J. F. Kennard and H. T. Faus. Journal American Institute of Electrical Engineers, May 1930, pages 343-345.

Paper describing the adaptation of the properties of a series of specially prepared nickel-copper alloys (designated "Calmaloy") which possess the property of a linear relation between magnetic permeability and temperature over a wide range, for the purpose of providing compensation for millivolt meters used in connection with thermocouples for determining the temperatures of air-cooled aircraft motors. Curves are given indicating the accuracy of the compensation obtained.

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DEMAND METERS

Gas
American Meter Co.
Foxboro Company

Electric
General Electric Co.
Westinghouse Elec. & Mfg. Co.

DENSITOMETERS
Akatos, Inc.

DENSOMETERS
H. Z. Schniewind

DIVIDING HEAD

Optical
Bausch & Lomb Optical Co.

DIVIDING MACHINES
Gaertner Scientific Corp.

DRAFT GAGES—see Gages

DYNAMIC BALANCING EQUIPMENT
Commercial Engg. Labs.

EARTH CURRENT METERS
Rawson Elec. Inst. Co.

ELECTRIC TELEMETER
Southwark Fdry. & Mach. Co.

ELECTRIC WAVE FILTER SECTIONS
General Radio Company

EMPLOYEES' "IN AND OUT" TIME RECORDERS
Stromberg Electric Co.

ENGINE INDICATORS
Commercial Engg. Labs.
Lehmann & Michels

EXTENSOMETER
H. Z. Schniewind
Southwark Fdry. Mach. Co.

FATIGUE TESTERS
H. Z. Schniewind

FAULT FINDERS
General Radio Co.
Leeds & Northrup Co.
Rubicon Company
Weston Electrical Inst. Corp.

FLASH & BURNING POINT TESTERS
Akatos, Inc.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Co.

FLOW METERS
American Meter Co.
Brown Instrument Co.
Foxboro Co.
Meriam Co.

FLUXMETERS
Leeds & Northrup Co.
Rawson Electrical Instr. Co.

FOLDING TESTER
H. Z. Schniewind

FREQUENCY METERS

Indicating
General Electric Co.
Jewell Electrical Instrument Co.
Leeds & Northrup Co.
Westinghouse Elec. & Mfg. Co.
Weston Elec. Inst. Corp.

Controlling
Leeds & Northrup Co.

Recording
Bristol Company
Esterline-Angus Company
Leeds & Northrup Co.

Standards
General Radio Co.

FUEL ANALYSIS APPARATUS
Burgess-Parr Co.

FUEL FLOW INDICATOR
Commercial Engg. Labs.

GAGE RODS
Tagliabue Mfg. Co., C. J.

GAGES

Absolute Pressure
Bristol Company
Brown Instrument Co.
Foxboro Co.
Meriam Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies

Amplifying
B. C. Ames Co.
Federal Products Corp.

Comparator
B. C. Ames Co.
Federal Products Corp.

Cylinder
B. C. Ames Co.
Federal Products Corp.

Depth
B. C. Ames Co.
Federal Products Corp.

Dial
B. C. Ames Co.
Federal Products Corp.
H. Z. Schniewind

Differential Pressure
American Meter Co.
Brown Instrument Co.
Foxboro Co.
Claud S. Gordon Co.
Meriam Co.
Tagliabue Mfg. Co., C. J.

Draft
Bristol Company
Brown Instrument Co.
Foxboro Co.
Claud S. Gordon Co.
Meriam Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies

Drill
Bausch & Lomb Optical Co

Grinding
Federal Products Corp.

Liquid Level
Bristol Company
Brown Instrument Co.
Foxboro Co.
Leeds & Northrup Co.
Meriam Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies

Loss of Head
Brown Instrument Co.
Foxboro Co.
Meriam Co.

Pitch Diameter
Federal Products Corp.

Pocket
H. Z. Schniewind

Pressure
American Meter Co.
Bristol Company
Brown Instrument Co.
Foxboro Co.
Claud S. Gordon Co.
Leeds & Northrup Co.
Meriam Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies

Pressure-Temperature
Bristol Company
Brown Instrument Co.
Foxboro Co.
Claud S. Gordon Co.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Cos.

Industrial Temperature Measuring Instruments. Instrument World, July 1930, pages 61-64. Brief Discussion.

Automatic Control of Temperature. Instrument World, July 1930, pages 65-66. Brief discussion.

Thermal Transmission of Fabrics. E. Freedman. Preprint 106, American Society for Testing Materials, June 23-27, 1930, 10 pages.

Tests of heat transmission through porous materials such as cotton and wool fabrics were conducted in moving air by using a calorimeter containing an electric heater and surrounded by the material under test, the material being exposed to temperatures down to 20°F. and wind velocities up to 25 miles per hour. The electrical input to the heater was measured in the usual way when the temperature difference, as indicated by specially-constructed xylene liquid thermometers, became constant. The specimens under test had an area of approximately 100 sq. in. The energy input for temperature differences of 70°F. was found to vary from 15 watts for good blanket materials to 135 watts for gauze fabrics, the input depending on texture and wind velocity. The method of test is sensitive and the results reproducible.

Low Temperature Thermostat. The Compressibility Isotherms of Hydrogen, Nitrogen and a 3:1 Mixture of these Gases at Temperatures of -70, -50, and 20° and at Pressures to 1000 Atmospheres. Edward P. Bartlett, Harry C. Hetherington, Hamline M. Kvalnes & Thomas H. Tremearne. Journal American Chemical Society, April 1930, page 1365.

Diagram and brief description of the thermostat arrangement are given and has some features that may prove helpful in low temperature constant temperature baths.—M. E. H.

PRESSURE

A New Measuring Instrument for Pressures in Mines (Ein neues Messgeraet fuer Druckmessungen in Bergwerken). E. Stach & H. Kirsten. Messtechnik, May 1930, pages 119-123.

In order to get a proper idea as to the efficiency of mine ventilation the instrument of the Askania Works has been developed to measure pressures of 500-900 mm Hg. The Statoscope is an aneroid barometer with direct reading pressure scale.—Ha.

Pressure Meters of Glass without Mercury (Quecksilber freie Druckmesser aus Glas). H. Ebert. Glass und Apparat, June 1930, pages 3-4.

Review of instruments for measuring pressures with indication of place of description.—Ha.

SPEED, ACCELERATION AND TIME

The Time-Recording Apparatus of Loebner (Der Zeitdruck-Registrierapparat von Loebner). Zeitschrift fuer Mechanik und Prazision, June 15, 1930, pages 6-8.

This instrument is mainly intended for sporting purposes, but also for scientific and technical measurements. It contains a clock, time recorder, starting pistol, finish relay, and a battery. The whole sequence of measurements is automatic.—Ha.

Precise Measurement of Short Time Intervals by Use of the Microschronographic Wheel. G. M. Town. Review of Scientific Instruments, Aug. 1930, pages 449-465.

Apparatus and methods are described by which time intervals may be measured to a precision of twenty microseconds. The duration of the time interval may be anything between twenty microseconds and ten seconds or even longer. The record obtained is continuous, making it possible to locate any event within the time interval to this same precision. The method is not limited to the measurement of electrical quantities. The application of the method to the determination of the speed of a rotating shaft is given in detail.

PHYSICAL TESTING

The Relative Safety of Mild and High-Tension Alloy Steels. Bernard P. Haigh. Automobile Engineer, Feb. 1930, pages 70-78.

Discuss the fatigue of metals and the instruments used to measure fatigue. Discuss the Wöhler, Haigh and other testing machines. The machines mentioned will test up to six tons.—R. H. P.

Single Strand Tester. Textile World, May 17, 1930, page 59.

An improved type of testing machine for testing single strands of rayon and other materials of low tensile strength is described. It is stated that the machine, manufactured by Henry L. Scott Co., Providence, R. I., is extremely accurate and sensitive and that it gives reliable results on single strands of wet rayon—G. N.

Toledo Auto-Gage Chassis Spring Scale. Automotive Industries, June 21, 1930, page 952.

Description of an improved chassis spring testing machine.—G. N.

Relationships Between Rockwell and Brinell Numbers. S. N. Petrenko. Bureau of Standards Journal of Research, July 1930, pages 19-50.

Comparative Rockwell and Brinell tests were made on a great variety of ferrous and nonferrous metals. Relationships between Brinell and Rockwell numbers, based on certain simplifying assumptions, are:

$$\text{Brinell number} = \frac{\text{constant}}{130 - \text{Rockwell ball number}}$$

and

$$\text{Brinell number} = \frac{\text{constant}}{(100 - \text{Rockwell cone number})^2}$$

These equations were used as guides in finding empirical formulas which fitted most closely the values determined experimentally. Of all the experimental values obtained in this investigation very few differed by more than 10% from values obtained from these empirical equations. Empirical equations were found giving the tensile strength of steels in terms of their Rockwell numbers. Experimental values checked these equations within an error of plus or minus 15%.

A Magnetic Strain Gage. J. P. Shamberger. Preprint 107, American Society for Testing Materials, June 23-27, 1930, 7 pages.

For a long time there has existed a need for an instrument that would determine stress accurately in mechanical structures, not only under static but also under dynamic conditions. The Westinghouse Electric and Manufacturing Co. has recently developed such an instrument which is termed a magnetic strain gage, a description of which is given in this paper. This gage can be used for measuring strain and therefore determining stress under dynamic conditions in such structures as railroad rails, locomotive side rods, bridge members, shafts, wheels and many other structures. It is equally adapted for determining stress under static conditions in the laboratory or in the field. The gage is simple in construction and rugged and requires no delicate handling, yet possesses a high degree of sensitivity and accuracy.

Pressure & Vacuum
Bristol Company
Brown Instrument Co.
Charles Engelhard, Inc.
Foxboro Co.
General Electric Co.
Claud S. Gordon Co.
Leeds & Northrup Co.
Meriam Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies

Profile
Bausch & Lomb Optical Co.

Rain
Taylor Instrument Companies

Recording

Distance
Bristol Company
Brown Instrument Co.
Esterline-Angus Company
Claud S. Gordon Co.

Strain
Southwark Fdry. & Mach. Co.

Thickness
B. C. Ames Co.
Esterline-Angus Company
H. Z. Schniewind

Volume
American Meter Co.
Brown Instrument Co.
Foxboro Co.
Meriam Co.

Water Level for Boilers
Bristol Company
Brown Instrument Co.
Foxboro Co.

Wind
Brown Instrument Co.
Taylor Instrument Companies

GALVANOMETERS
Brown Instrument Co.
Charles Engelhard, Inc.
General Radio Co.
Claud S. Gordon Co.
Jewell Electrical Instrument Co.
Leeds & Northrup Co.
Rubicon Company
Westinghouse Elec. & Mfg. Co.
Weston Electrical Inst. Corp.

GAS ANALYTICAL METERS

Chemical
American Meter Co.
Tagliabue Mfg. Co., C. J.

Electrical
Brown Instrument Co.
Charles Engelhard, Inc.
Leeds & Northrup Co.

GAS LEAK INDICATORS
Taylor Instrument Companies

GAS-METERS
American Meter Co.
Brown Instrument Co.
Foxboro Co.
Meriam Co.

GASOMETERS
American Meter Co

GEOPHYSICAL INSTRUMENTS
Akatos, Inc.

GOVERNORS

Laboratory Dry & Wet Gas
American Meter Co.

Pressure
Bristol Company
Brown Instrument Co.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.

Pump
Tagliabue Mfg. Co., C. J.

GLASS STRAIN TESTERS
Akatos, Inc.

GREASE TESTING APPARATUS
Tagliabue Mfg. Co., C. J

GROUND DETECTORS
Leeds & Northrup Co.
Rubicon Company
Westinghouse Elec. & Mfg. Co.
Weston Electric Inst. Corp.

GROUND-OHMER
Leeds & Northrup Co.
Herman H. Sticht & Company

GYPSUM TESTING INSTRUMENTS
H. Z. Schniewind

HARDNESS TESTERS
Akatos, Inc.
Claud S. Gordon Co.
H. Z. Schniewind
Wilson-Maeulen Company, Inc.

HARMONIC ANALYZERS
Leeds & Northrup Co.

HELIOSTATS
Gaertner Scientific Corp.

HIGH FREQUENCY APPARATUS

HIGH VOLTAGE

Indicators

Measuring Devices
General Electric Co.
Westinghouse Elec. & Mfg. Co

Testing Devices
General Electric Co.
Westinghouse Elec. & Mfg. Co.

HUMIDITY CONTROLLERS
Bristol Company
Charles Engelhard, Inc.
Foxboro Co.

HUMIDITY RECORDERS

Wet & Dry Bulb Thermometers
Bristol Company
Brown Instrument Co.
Foxboro Co.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies

HYDROGEN ION METERS

Indicating
Leeds & Northrup Co.
Rubicon Company

Controlling, Recording
Leeds & Northrup Co.

HYDROMETERS
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies

HYGROMETERS
Brown Instrument Co.
Foxboro Co.
H. Z. Schniewind
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies

IMPACT HARDNESS TESTER
H. Z. Schniewind

IMPACT TESTING MACHINES
Akatos, Inc.
H. Z. Schniewind

Alternating

INDICATORS—See Gauges

INDUCTANCES
General Radio Co.
Leeds & Northrup Co.
Rubicon Company

INSTRUMENT BOOKS
Instruments Publishing Co.

INSTRUMENT CALIBRATION AND REPAIRS
Claud S. Gordon Co.
Jewell Electrical Instrument Co.
Rubicon Company

INSTRUMENT TRANSFORMERS
General Electric Co.
Jewll Electrical Instrument Co.
Westinghouse Elec. & Mfg. Co.
Weston Electrical Inst. Corp.

INSULATION TESTING EQUIPMENT
General Electric Co.
Leeds & Northrup Co.
Rubicon Company
Westinghouse Elec. & Mfg. Co.

INTEGRAPHS & INTEGRATORS
Leeds & Northrup Co.

INTERFEROMETERS
Gaertner Scientific Corp.

JOB TIMING RECORDERS
Stromberg Electric Co.

KEYS AND SWITCHES
General Radio Co.
Leeds & Northrup Co.
Rubicon Company

KILNBOY
Foxboro Co.

KILOVOLT AMPRERE METERS
Esterline-Angus Company

KLYDONOGRAPHS
Westinghouse Elec. & Mfg. Co.

LACTOMETERS
Tagliabue Mfg. Co., C. J.

LENGTH MEASURING MACHINES
Gaertner Scientific Corp.
H. Z. Schniewind

LEVELS

Centering
Bausch & Lomb Optical Co.

Engineer's, Wye, Precision

Prism
Taylor Instrument Companies

LIME TESTING INSTRUMENTS

LOCOMOTIVE INDICATORS
Lehmann & Michels

LUSTER METERS
Akatos, Inc.

MAGNETOMETERS
Rubicon Company

MANOMETERS
American Paulin System, Inc.
Brown Instrument Co.
Foxboro Co.
Meriam Co.

MASTER CLOCKS
Gaertner Scientific Corp.
Stromberg Electric Co.

MEASUREMENT BOOKS
Instrument Publishing Co.

MEGOHMMETERS
Leeds & Northrup Co.
Rubicon Company
Herman H. Sticht and Company

MEGOHM VOLTMETERS
Jewell Electrical Instrument Co.
Weston Electrical Inst. Corp.

MELTING POINT APPARATUS
Claud S. Gordon Co.
Tagliabue Mfg. Co., C. J.

METER PROVERS, Gas
American Meter Co.

METER TESTERS, Gas
American Meter Co.

MICROMETERS
Gaertner Scientific Corp.
H. Z. Schniewind

MICROAMMETERS
General Electric Co.
Jewell Electrical Instrument Co.
Rawson Electrical Instrument Co.
Weston Electrical Inst. Corp.
Wilson-Maeulen Company, Inc.

MICROFARADMETERS
General Radio Co.
Jewell Electrical Instrument Co.
Leeds & Northrup Co.
Rubicon Company
Weston Electrical Inst. Corp.

MICRO PYROMETERS
Akatos, Inc.

MICROSCOPES

Brinell
Bausch & Lomb Optical Co.
Gaertner Scientific Corp.
Claud S. Gordon Co.
H. Z. Schniewind
Spencer Lens Co.

Metallographic
Akatos, Inc.
Bausch & Lomb Optical Co.
Claud S. Gordon Co.
Spencer Lens Co.

Petrographical
Akatos, Inc.
Bausch & Lomb Optical Co.
Spencer Lens Co.
Toolmakers'
Bausch & Lomb Optical Co.
Gaertner Scientific Corp.
Spencer Lens Co.

MICROTOMES
Bausch & Lomb Optical Co.
Spencer Lens Co.

MILLIAMMETERS
Charles Engelhard, Inc.
General Electric Co.
General Radio Co.
Jewell Electrical Instrument Co.
Rawson Electrical Instrument Co.
Weston Electrical Inst. Corp.
Wilson-Maeulen Company, Inc.

MILLIVOLTMETERS
Bristol Company
Charles Engelhard, Inc.
General Electric Co.
Jewell Electrical Instrument Co.
Rawson Electrical Instrument Co.
Taylor Instrument Companies
Weston Electrical Inst. Corp.
Wilson-Maeulen Company, Inc.

MOTOR RADIATOR VALVES
Minneapolis-Honeywell Co.

MOTION RECORDERS
Mechanical
Bristol Company
Foxboro Co.
Lehmann & Michels

MULTIMETERS
Rawson Electrical Instrument Co.

MULTIPLIERS
Jewell Electrical Instrument Co.
Leeds & Northrup Co.
Weston Electrical Inst. Corp.

NEON FILLED TUBES

NEPHELOMETERS
Akatos, Inc.

OHM METERS
General Radio Co.
Jewell Electrical Instrument Co.
Leeds & Northrup Co.
Rawson Electrical Instrument Co
Rubicon Company
Herman H. Sticht and Company
Weston Electrical Inst. Corp.

OIL METERS
Claud S. Gordon Co.

OIL TESTING APPARATUS
General Electric Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies

OPERATION RECORDERS
Electrical
Bristol Company
Brown Instrument Co.
Foxboro Co.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.

ORIFICE METERS
American Meter Co.
Brown Instrument Co.
Foxboro Co.
Meriam Co.

ORSAT APPARATUS

OSCILLOGRAPHS
General Electric Co.
General Radio Co.
Westinghouse Elec. & Mfg. Co.

OXYGEN RECORDERS
Charles Engelhard, Inc.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.

PANTOGRAPHS
Gaertner Scientific Corp.

PERFORMANCE METER

PERMEAMETERS
Leeds & Northrup Co.
Rubicon Company

PAPER TESTING INSTRUMENTS
H. Z. Schniewind
Spencer Lens Co.

PERISCOPES
Bausch & Lomb Optical Co.
Gaertner Scientific Corp.

PHASE INDICATOR
Westinghouse Elec. & Mfg. Co.

PHASE SEQUENCE INDICATOR
Herman H. Sticht Co.

PHOTOELECTRIC COLOR ANALYZERS
General Electric Co.

PHOTOELECTRIC COLOR COMPARATOR
General Electric Co.

PHOTO-ELECTRIC TUBES
General Electric Co.

PHOTOMETERS
Akatos, Inc.
American Meter Co.
Gaertner Scientific Corp.
Bausch & Lomb Optical Co.
Leeds & Northrup Co.

PHYSICAL TESTING MACHINES
Claud S. Gordon Co.
Lehmann & Michels
H. Z. Schniewind
Southwark Fdry. & Mach. Co.

PITOT TUBE METER
Brown Instrument Co.
Foxboro Co.

PLANIMETERS
Automatic Flow Record
Brown Instrument Co.
Linear
Brown Instrument Co.
Lehmann & Michels
Radial
American Meter Co.
Bristol Company
Foxboro Co.
Square Root
Foxboro Co.

POLARISCOPES
Akatos, Inc.
Gaertner Scientific Corp.

POSITION RECORDERS
Bristol Company
Esterline-Angus Company
Foxboro Co.

POTENTIAL DETECTORS
Leeds & Northrup Co.
Westinghouse Elec. & Mfg. Co.

POTENTIOMETERS—Indicating
Brown Instrument Co.
General Electric Co.
Claud S. Gordon Co.
Leeds & Northrup Co.
Rubicon Company
Recording & Controlling
General Electric Co.
Claud S. Gordon Co.
Leeds & Northrup Co.

POWER FACTOR METERS
Esterline-Angus Company
General Electric Co.
Jewell Electrical Instrument Co.
Westinghouse Elec. & Mfg. Co.
Weston Eelectrical Inst. Corp.

POWER FACTOR REGULATORS
Rubicon Company
Westinghouse Elec. & Mfg. Co.

PRESSURE RECORDERS
Esterline-Angus Company
Foxboro Co.

PRICESS TIMING AND SIGNALING INSTRUMENTS
Stromberg Electric Co.

PROGRAM INSTRUMENTS
Stromberg Electric Co.

PROJECTION LANTERNS
Bausch & Lomb Optical Co.
Spencer Lens Co.

PROTRACTOR
Optical
Bausch & Lomb Optical Co.

PSYCHROMETER
Recording
Bristol Company
Foxboro Co.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies
Sling
Taylor Instrument Companies

PYROMETERS
Optical
Claud S. Gordon Co.
Leeds & Northrup Co.
Pyrometer Instrument Company
Radiation
Indicating
Brown Instrument Co.
Claud S. Gordon Co.
Leeds & Northrup Co.
Pyrometer Instrument Company
Taylor Instrument Companies
Recording
Brown Instrument Co.
Leeds & Northrup Co.
Taylor Instrument Companies
Thermo-electric
Immersion
Bristol Company
Brown Instrument Co.
Charles Engelhard, Inc.
Claud S. Gordon Co.
Leeds & Northrup Co.
Pyrometer Instrument Company
Taylor Instrument Companies
Wilson-Maeulen Company, Inc.
Indicating
Bristol Company
Brown Instrument Co.
Charles Engelhard, Inc.
Claud S. Gordon Co.
Leeds & Northrup Co.
Taylor Instrument Companies
Westinghouse Elec. & Mfg. Co.
Wilson-Maeulen Company, Inc.
Recording and Controlling
Bristol Company
Brown Instrument Co.
Charles Engelhard, Inc.
Claud S. Gordon Co.
Leeds & Northrup Co.
Taylor Instrument Companies
Wilson-Maeulen Company, Inc.
Surface Contact
Bristol Company
Brown Instrument Co.
Charles Engelhard, Inc.
Claud S. Gordon Co.
Leeds & Northrup Co.
Pyrometer Instrument Company
Taylor Instrument Companies

RADIO FREQUENCY OSCILLATORS
General Radio Company

RADIO SET ANALYZERS
General Radio Company
Jewell Electrical Instrument Co.
Weston Electrical Inst. Corp.

RADIO TUBE CHECKERS
General Radio Company
Jewell Electrical Instrument Co.
Weston Electrical Inst. Corp.

RADIO TEST PANEL
Jewell Electrical Instrument Co.
Weston Electrical Inst. Corp.

REFRACTOMETERS
Akatos, Inc.
Bausch & Lomb Optical Co.
Spencer Lens Co.

REGULATORS—See Controls

RELAYS
General Electric Co.
General Radio Co.
Claud S. Gordon Co.
Jewell Electrical Instrument Co.
Leeds & Northrup Co.
Westinghouse Elec. & Mfg. Co.
Weston Electrical Inst. Corp.

REMOTE METERING EQUIPMENT
Bristol Company
Brown Instrument Co.
General Electric Co.
Leeds & Northrup Co.
Westinghouse Elec. & Mfg. Co.

RESISTANCES—Electrical
General Radio Co.
Leeds & Northrup Co.
Spencer Lens Co.

RHEOSTATS
General Radio Co.
Rubicon Company
Spencer Lens Co.

ROTOSCOPE
Commercial Engg. Labs.

RUBBER TESTING INSTRUMENTS
H. Z. Schniewind

SACCHARIMETERS
Akatos, Inc.
Bausch & Lomb Optical Co.
Spencer Lens Co.
Taylor Instrument Companies

SACCHROMETERS
Tagliabue Mfg. Co., C. J.

SALINITY INDICATORS
Leeds & Northrup Co.
Rubicon Company

SCALES
Amthor Testing Instrument Co
Gaertner Scientific Corp.
H. Z. Schniewind

SCRATCH HARDNESS TESTER

SEISMOGRAPHS
Akatos, Inc.

SERVICE RECORDERS
Esterline-Angus Company

SHUNT METERS

SHUNTS
Esterline-Angus Company
Jewell Electrical Instrument Co.
Leeds & Northrup Co.
Rubicon Company
Weston Electrical Inst. Corp.

SIGNALLING DEVICES—Automatic
Brown Instrument Co.
Stromberg Electric Co.

SLIDE RULES

SOIL PRESSURE CELLS

SPECIAL INSTRUMENTS
Burgess-Parr Co.
Meriam Co.
H. Z. Schniewind

SPECIAL ELECTRICAL INSTRUMENTS
Brown Instrument Co.
Charles Engelhard, Inc.
Esterline-Angus Company
General Radio Co.
Jewell Electrical Instrument Co.
Leeds & Northrup Co.
Rawson Electrical Instrument Co.
Rubicon Company
Weston Electrical Inst. Corp.

SPECIAL RECORDING DEVICES
Esterline-Angus Company

SPECIFIC GRAVITY APPARATUS, Gas,
American Meter Co.

SPECTROGRAPHS
Gaertner Scientific Corp.

SPECTROSCOPES
Akatos, Inc.
Bausch & Lomb Optical Co.
Gaertner Scientific Corp.
Spencer Lens Co.

SPECTROPHOTOMETERS
Akatos, Inc.
Bausch & Lomb Optical Co.
Gaertner Scientific Corp.

SPEED INDICATORS
See Tachometers

SPEED RECORDERS
Esterline-Angus Company

STANDARD CELLS
Weston Electrical Inst. Corp.

STEEL TAPES

STOP WATCHES
American Meter Co

STRAIN GAUGE
Southwark Fdry. & Mach. Co.

STRESS INDICATOR

STROBOSCOPES
Commercial Engg. Labs.

SULPHUR DIOXIDE METERS
American Meter Co.
Charles Engelhard, Inc.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.

SULPHUR DETERMINATION APPARATUS
Burgess-Parr Co.
Tagliabue Mfg. Co., C. J.

SUNSHINE RECORDERS
Charles Engelhard, Inc.
Leeds & Northrup Co.
Taylor Instrument Companies

SUPERPRESSURE CATALYST EQUIPMENT

SURGE INDICATORS
General Electric Co.

SURGE RECORDERS
Esterline-Angus Company
General Electric Co.

SYNCHRONIZING FORKS—Electrical
General Radio Co.
Leeds & Northrup Co.

TACHOSCOPES
Brown Instrument Co.

TACHOMETERS
Amthor Testing Instrument Co.
Bristol Company
Brown Instrument Co.
Esterline-Angus Company
Foxboro Co.
Jewell Electrical Instrument Co.
Leeds & Northrup Co.
Pyrometer Instrument Company
H. Z. Schniewind
Herman H. Sticht & Company
Westinghouse Elec. & Mfg. Co.
Weston Electrical Inst. Corp.

TELESCOPES
Bausch & Lomb Optical Co.
Gaertner Scientific Corp.

TENSILE TESTERS FOR PAPER WIRE, SHEETS, ETC.
Amthor Testing Instrument Co.
H. Z. Schniewind

TENSIOMETERS
American Paulin System, Inc.

TENSOMETER (Huggenberger)
Southwark Fdry. & Mach. Co.

TESTERS, Gas
American Meter Co.

TESTING MACHINE—Universal
Claud S. Gordon Co.
H. Z. Schniewind
Southwark Fdry. & Mach. Co.

TEXTILE TESTING INSTRUMENTS
H. Z. Schniewind

THEODOLITES

THERMIONIC OXIDE RECTIFIERS
General Electric Co.

THERMO-JUNCTIONS (Electric)
General Radio Co.
Rawson Electrical Instrument Co.

THERMOMETERS

Gas Filled
Bristol Company
Brown Instrument Co.
Foxboro Co.
Claud S. Gordon
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies

Mechanical
American Meter Co.
Brown Instrument Co
Foxboro Co.
Tagliabue Mfg. Co. C. J

Mercurial
Claud S. Gordon Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies

Resistance
Brown Instrument Co.
Charles Engelhard, Inc.
Claud S. Gordon Co.
Leeds & Northrup Co.
Wilson-Maeulen Co., Inc.

Vapor-Tension
Bristol Company
Brown Instrument Co.
Foxboro Co.
Claud S. Gordon Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies

Wet & Dry Bulb
Bristol Company
Brown Instrument Co.
Charles Engelhard, Inc.
Foxboro Co.
Claud S. Gordon Co.
Leeds & Northrup Co.
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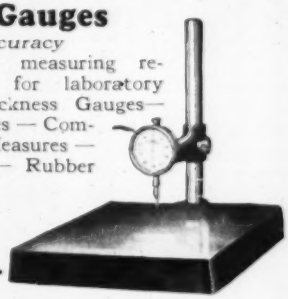

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MEASUREMENT OF AIR FLOW.

E. OWER, INSTRUMENTS, Vol. 3, October 1930, pages 623-632, 3 figs.

Chapter VI (cont'd) The Venturi tube and the shaped nozzle are considered.

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DR. WALTER BLOCK, INSTRUMENTS, Vol. 3, October 1930, pages 633-644.

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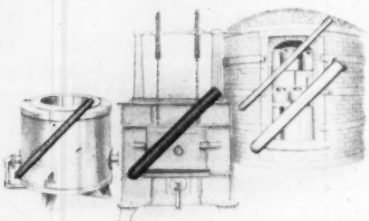

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